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**Source Testing of a Stationary Coke-Side
Enclosure. Volume 1. Burns Harbor Plant
Bethlehem Steel Corp., Chesterton, Ind.**

Clayton Environmental Consultants, Inc., Southfield, Mich

Prepared for

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Stationary Source
Enforcement Series

**SOURCE TESTING
OF A
STATIONARY
COKE-SIDE
ENCLOSURE**

**BURNS HARBOR PLANT
BETHLEHEM STEEL CORPORATION
CHESTERTON, INDIANA**



**U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF ENFORCEMENT
OFFICE OF GENERAL ENFORCEMENT
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(Volume 1 of 13)

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Bathishem Steel Corporation
Chesterton, Indiana**

**Contract No. 68-02-1408
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Prepared for:

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Washington, D.C. 20460**

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12

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id

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TABLE OF CONTENTS

<u>VOLUME 1</u>	<u>PAGE</u>
GLOSSARY OF TERMS	v
LIST OF FIGURES	viii
LIST OF TABLES	ix
LIST OF APPENDICES	xi
1.0 INTRODUCTION	1
2.0 SUMMARY AND CONCLUSIONS	12
2.1 Coke-Side Particulate Emissions	12
2.1.1 Overall continuous coke-side particulate emissions	12
2.1.2 Continuous particulate emissions from the exhaust duct	13
2.1.3 Peak particulate emissions from the exhaust duct	13
2.1.4 Fugitive particulate emissions from the shed	14
2.1.5 Particulate emissions for pushing operations	14
2.1.6 Particulate emissions for non-pushing operations	14
2.2 Shed Particulate Capture Efficiency	15
2.2.1 Evaluation of shed capture efficiency	15
2.2.2 Possible causes of leakage	19
2.3 Chemical Composition of Particulate Emissions ...	16
2.4 Particle Size Distribution	16
2.5 Emissions of Other Materials	16
2.6 Dustfall Measurements	16
2.7 Indices of Visible Emissions	17
2.7.1 Degree of greenness	17
2.7.2 Opacity	17

2.7.3 Percent of doors leaking	18
2.8 Process and Emissions Correlations	18
2.9 Representativeness of Process and Shed Conditions	19
3.0 PROCESS DESCRIPTION AND OPERATIONS	20
3.1 Process Description	20
3.2 Representativeness of Process and Shed Con- ditions	22
3.2.1 Criteria for comparison	23
3.2.2 Conditions during sampling periods	28
3.3 Identification of Possible Normalizing Factors..	32
4.0 SAMPLING AND ANALYTICAL METHODS	33
4.1 Test Protocol	33
4.2 Location of Sampling Points	34
4.3 Continuous Particulate Emissions from Shed Exhaust Duct	35
4.4 Determination of Peak Particulate Emission Period	39
4.5 Peak Particulate Emissions from Shed Exhaust Duct	43
4.6 Particle Size Distribution.....	43
4.7 Emissions of Other Materials	44
4.8 Dustfall Measurements	45
4.9 Subjective and Visual Emission Parameters	46
4.9.1 Degree of greenness	46
4.9.2 Opacity of shed exhaust	47
4.9.3 Percent of doors leaking.....	47
4.9.4 Visual estimates of fugitive emissions...	48
4.10 Fugitive Particulate Emissions From the Shed ...	48
4.11 Calibrations, Quality Assurance, and Sampling Integrity	49

	<u>Page</u>
5.0 PRESENTATION AND DISCUSSION OF RESULTS	51
5.1 Coke-Side Particulate Emissions	51
5.1.1 Continuous particulate emissions from the exhaust duct	51
5.1.2 Fugitive particulate emissions	53
5.1.3 Overall continuous coke-side particulate emissions	54
5.1.4 Peak particulate emissions from the shed	55
5.1.5 Particulate emissions for pushing operations	59
5.1.6 Particulate emissions for non-pushing operations	62
5.2 Particulate Capture Efficiency of the Shed	65
5.2.1 Evaluation of shed capture efficiency	65
5.2.2 Possible causes of leakage	68
5.3 Chemical Composition of Particulate Emissions ...	69
5.4 Particle Size Distribution	69
5.5 Emissions of Other Materials	77
5.6 Indices of Visible Emissions	80
5.6.1 Degree of greenness	80
5.6.2 Opacity	88
5.6.2.1 Emissions from exhaust duct	88
5.6.2.2 Fugitive emissions	89
5.6.3 Percent of dust leaking	90
5.7 Emission-Related Correlations	92
5.7.1 Correlations between emission factors and indices of visible emissions	92
5.7.2 Correlations between emission factors and process conditions	93
5.7.3 Correlations involving particle size distributions	94
5.7.4 Correlations between indices of visible emissions and process conditions	94
5.7.5 Correlations among visible emissions measurements	101
5.8 Effect of the Shed Upon Dustfall	103

	<u>Page</u>
5.9 Impact of the Shed Upon Airborne Agents Within the Shed	115
5.10 Precision of Test Results	115
6.0 REFERENCES	117
7.0 SOME ANTICIPATED QUESTIONS AND ANSWERS RELATED TO THIS PROJECT	119

VOLUME 2

Appendices A-E (See page xi for titles)

VOLUME 3

Appendices F-H (See page xi for titles)

VOLUME 4

Appendices I-O (See page xi for titles)

VOLUME 5

Appendices P-MM (See pages xi and xii for titles)

VOLUME 6

Appendices NN-WW (See page xiii for titles)

VOLUME 7

Appendices XX-ZZ (See page xiii for titles)

VOLUME 8

Appendix AAA (See page xiii for titles)

VOLUME 9

Appendix BBB (See page xiii for titles)

VOLUME 10

Appendix CCC (See page xiii for titles)

VOLUME 11

Appendix DDD (See page xiii for titles)

VOLUME 12

Appendices EEE-GGG (See page xiv for titles)

GLOSSARY OF TERMS

1. Abnormal operating conditions

Hot coking time outside the normal range of hot coking time or any coke pushing stoppage greater than 30 minutes duration.

2. Atypical operating conditions

Extremely infrequent major process changes (or upsets).

3. Coke-pushing emissions

An intermittent source emission lasting about 15 to 45 seconds, occurring on an irregular cycle with an average interval between pushes of 13 minutes.

4. Coke-pushing operations emissions

The aggregate of two source emissions: 1) coke-pushing emissions and 2) quench car movement emissions which occur under the shed.

5. Coke side

That side of a coke-oven battery from which the ovens are emptied of coke.

6. Continuous particulate emissions

The mass particulate emissions measured on the coke side of the coke battery on a continuous basis, spanning periods when pushes occurred as well as intervals between pushes (unless process upsets or downtime exceeded 30 minutes).

7. Degree of greenness of a coke-oven push

A subjective, visual estimate of the quantity of emissions released during a single coke-oven push by estimation of the plume obscuration immediately above the quench car.

8. Door leakage

Any visible emissions observed emanating from coke-side oven doors, push-side oven doors, or push-side chuck doors.

9. Filterable particulate

Material captured at a specified temperature, pressure, and chemical activity, on or before the front filter in a particulate sampling train.

10. Fugitive particulate emissions

Particulate emissions which escaped capture by the shed and passed unrestrained into the atmosphere. This does not include emissions resulting from quench car travel outside the shed.

11. Minimum coking time

The elapsed time, in minutes, specified by the operator of the coke production facility as being the minimum net coking time necessary to provide adequate quality coke for production purposes.

12. Net coking time

The elapsed time, in minutes, between the charging of a coke oven with coal and the pushing of that same oven.

13. Normal operating conditions

Any typical operating conditions not abnormal.

14. Normalisation factor

A variable used to relate a mass emission rate to the rate of processing. An example is "tons of dry coal charged."

15. Overall continuous coke-side particulate emissions

The sum of the continuous particulate emissions and the continuous fugitive particulate emissions.

16. Peak particulate emissions

The mass particulate emissions from the exhaust dust measured on the coke side of the coke battery during only the initial 3-minute periods beginning with the commencement of each coke-oven push.

17. Precision of a test result

The statistical confidence interval associated with the mean value of a series of replicate measurements at a decision-risk level of five percent.

18. Push-only particulate emissions

The mass particulate emissions measured on the coke side of the coke battery and resulting only from the pushing operations.

19. Quench car movement emissions

An intermittent source emission emanating from the coke in the quench car and lasting about 15-45 seconds, from the end of a coke-oven push until the quench car exits from the shed.

20. Total particulate

Material captured at a specified temperature, pressure, and chemical activity in the entire particulate sampling train, i.e., filterable and condensable fractions.

21. Typical operating conditions

Any process operating conditions not atypical.

LIST OF FIGURES

		PAGE
FIGURE 3.1-1	Schematic Diagram of By-Product, Metallurgical Coke Manufacturing Facility with Dustfall Sites	21
FIGURE 3.1-2	Schematic Diagram of Coke-Side Shed	23
FIGURE 3.1-3	Schematic Diagram of Coke-Side Shed End Openings	24
FIGURE 4.3-1	Schematic Diagram of Sampling Point Locations for "Continuous" Particulate Samples	36
FIGURE 4.3-2	Schematic Diagram of Sampling Point Locations for "Peak" Particulate Samples	37
FIGURE 4.3-3	Schematic Diagram of Sampling Point Locations for All Samples Except Particulate	38
FIGURE 4.4-1	Sequential Filter Opacity Test on February 24, 1973	40
FIGURE 4.4-2	Sequential Filter Opacity Test on March 3, 1973	41
FIGURE 5.1.5	Schematic Diagram of Sampling Schedule	61
FIGURE 5.4	Particle Size Distributions in Exhaust Duct	74
FIGURE 5.7.4-1	Net Coking Time Versus Opacity for Particulate Sampling Days	96
FIGURE 5.7.4-2	Degree of Greenness Versus Net Coking Time for Particulate Sampling Days	98
FIGURE 5.7.4-3	Opacity Versus Flue Temperature for Particulate Sampling Days	99
FIGURE 5.7.4-4	Degree of Greenness Versus Flue Temperature for Particulate Sampling Days	100
FIGURE 5.7.5-1	Opacity Versus Degree of Greenness for Particulate Sampling Days	102
FIGURE 5.7.5-2	Composite Graph of Shed Exhaust Duct Opacity Versus Time	104
FIGURE 5.7.5-3	Shed Exhaust Duct Opacity Versus Time for Various Net Coking Times	105

LIST OF TABLES

		<u>PAGE</u>
TABLE 1.0-1	Generalized Roster of Emissions Investigations	3
TABLE 1.0-2	Purpose(s) for Sampling Each Contaminant	5
TABLE 1.0-3	Project Participants	10
TABLE 3.2.1	Pertinent Parameters	27
TABLE 3.2.2-1	Comparison of Key Process Parameters (Battery No. 1)	29
TABLE 3.2.2-2	Comparison of Key Process Parameters (Battery No. 2)	30
TABLE 4.4	Determination of Peak Particulate Emission Period From the Exhaust Duct	42
TABLE 5.1.1	Summary of Continuous Particulate Emissions From the Battery No. 1 Exhaust Duct	52
TABLE 5.1.2	Measured Fugitive Particulate Emissions Escaping From the Shed	53
TABLE 5.1.3	Summary of Overall Continuous Particulate Emissions From the Shed	57
TABLE 5.1.4	Summary of Peak Particulate Emissions From the Battery No. 1 Exhaust Duct	58
TABLE 5.1.5	Calculation of Filterable Particulate Emission Factor for Pushing Operations	63
TABLE 5.1.6	Calculation of Filterable Particulate Emission Factor for Non-Pushing Operations	64
TABLE 5.3-1	Summary of Metals and Sulfate Content of Particulate Samples	70
TABLE 5.3-2	Summary of Average Rates of Particulate Emissions From Exhaust Duct	71
TABLE 5.3-3	Summary of Water Soluble pH and Acidity/Alkalinity of Particulate Samples	73
TABLE 5.4	Particulate Concentration and Acetone-Soluble Content of Particle Size Samples	76
TABLE 5.5	Summary of Average Emission Rates of "Other" Emissions	78

		<u>PAGE</u>
TABLE 3.6.1-1	Characteristics of Individual Pushes During Particulate Sampling — Continuous Particulate Test No. 1	81
TABLE 3.6.1-2	Characteristics of Individual Pushes During Particulate Sampling — Peak Particulate Test No. 1	82
TABLE 3.6.1-3	Characteristics of Individual Pushes During Particulate Sampling — Continuous Particulate Test No. 2	83
TABLE 3.6.1-4	Characteristics of Individual Pushes During Particulate Sampling — Peak Particulate Test No. 2	84
TABLE 3.6.1-5	Characteristics of Individual Pushes During Particulate Sampling — Continuous Particulate Test No. 3	85
TABLE 3.6.1-6	Characteristics of Individual Pushes During Particulate Sampling — Peak Particulate Test No. 3	85
TABLE 3.6.1-7	Push Characteristics During Particle Size Sampling	87
TABLE 3.6.3	Door Leakage on Particulate Sampling Days	91
TABLE 3.8-1	Summary of Dustfall Measurements at Batteries 1 and 2	107
TABLE 3.8-2	Summary of Acetone-Soluble and Cyclohexane-Soluble Content of Selected Dustfall Samples	109
TABLE 3.8-3	Summary of pH of Selected Dustfall Samples	110
TABLE 3.8-4	Format Used for Analyses of Dustfall Data ($\mu\text{m}^3/\text{wh}$)	113

LIST OF APPENDICES

VOLUME 2

- A BBO Coke-Oven Pushing Schedule
- B BBO Pusher Reports
- C BBO Coke-Oven Daily Data (Coal and Coke Analyses)
- D BBO Coal Charge Rate and Coal Analyses
- E BBO Coke-Oven Fuel-Gas Analyses

VOLUME 3

- F BBO Coal Weights for Each Charge
- G BBO Cross-Wall Temperature Graphs
- H BBO Full-Span Pyrometer Data

VOLUME 4

- I BBO Oven Pressure and Temperature Data
- J BBO Collector-Main Pressure and Underfire Gas Flow Data
- K BBO Flue Inspection Reports
- L BBO Coke Inspection Reports
- M BBO Fan Curves and Fan Power Data
- N BBO Visible Emissions Ratings
- O BBO Meteorological Data

VOLUME 5

- P EPA Method 1 — Sample and Velocity Traverses for Stationary Sources
- Q EPA Method 2 — Determination of Stack Gas Velocity and Volumetric Flowrate (Type S Pitot Tube)
- R EPA Method 3 — Determination of Particulate Emissions from Stationary Sources
- S Determination of Particulate Emissions from Coke-Oven Pushing

T	Determination of Peak Particulate Emission Period from an Exhaust Duct
U	Determination of Particle Sizing During Coke-Oven Pushing
V	EPA Method 8 — Determination of Sulfuric Acid Mist and Sulfur Dioxide Emissions from Stationary Sources
W	EPA Method 11 — Determination of Hydrogen Sulfide Emissions from Stationary Sources
X	Determination of Ammonia Emissions from Coke-Oven Pushing
Y	Determination of Various Emissions Absorbed in Sodium Hydroxide from Coke-Oven Pushing
Z	Determination of Various Emissions Adsorbed on Activated Carbon from Coke-Oven Pushing
AA	Determination of Various Emissions Captured in a Glass Gas Burette During Coke-Oven Pushing
BB	Determination of Various Emissions Absorbed in Cyclohexane from Coke-Oven Pushing
CC	Determination of Dustfall (Particulate Fallout) Near Coke Ovens
DD	Determination of Degree of Greenness of a Coke-Oven Push
EE	EPA Method 9 — Visual Determination of the Opacity of Emissions from Stationary Sources
FF	Determination of the Percent of Doors Leaking
GG	Determination of Estimated Fugitive Emissions from Coke-Oven Pushing
HH	Assessment of the Fugitive Particulate Emissions Escaping from a Coke-Side Shed
II	Calibration Procedures
JJ	Calibration Data
KK	Void Samples
LL	Field Sampling Data
NN	Analytical Data

VOLUME 6

- NH Chain-of-Custody Procedures for Air Pollution Emission Sampling
- OO Example Calculations
- PP Correspondence from Bethlehem Steel Corporation
- QQ Results of Previous RBC Sampling
- RR Results of Continuous Particulate Sampling
- SS Results of Peak Particulate Sampling
- TT Results of Particle Size Sampling
- UU Results of Sampling for "Other" Emissions
- VV EPA Degree-of-Greenness Data
- WW EPA Evaluation of Visible Emissions Exhausted from the Shed

VOLUME 7

- XX EPA Evaluation of Visible Emissions for Shed End Leakage
- YY EPA Door Leak Observations
- ZZ Push Emission Charts — Battery No. 1

VOLUME 8

- AAA Record for Coke-Side and Push-Side Doors — Battery No. 1

VOLUME 9

- BBB Shed Capture Performance and Miscellaneous Data — Battery No. 1

VOLUME 10

- CCC Push Emission Charts — Battery No. 2

VOLUME 11

- DDD Record for Coke-Side and Push-Side Doors — Battery No. 2

VOLUME 11

nnn Preliminary Tabulations Forwarded to EPA

yyy Additional Attempted Correlations

ooo Results of Dustfall Sampling

1.0 INTRODUCTION

The U.S. Environmental Protection Agency commissioned Clayton Environmental Consultants, Inc. (Task 10, Contract No. 68-02-1408) to quantify the nature and extent of particulate and gaseous emissions typically emanating from the coke side of Coke Battery No. 1 at the Burns Harbor plant of Bethlehem Steel Corporation in Chesterton, Indiana. This information was obtained to help provide a basis for:

1. Development of EPA policy on coke-side coke battery emissions and their control;
2. Assessment of the adequacy of State Implementation Plans to achieve Primary Air Quality Standards in areas contiguous to coke plants; and
3. Assessment of the adequacy of control devices being proposed for abatement of such emissions.

Measurement of the normally fugitive coke-side emissions was facilitated at Burns Harbor by the existence of a permanent, 400-foot long, canopy-type hood, commonly termed "coke-side shed," that semi-enclosed the coke side of Battery No. 1.

The following two major components comprised the coke-side emissions released into the shed:

1. Coke-pushing operation emissions resulting from:
 - a. Coke pushing — an intermittent source emission lasting about 15 to 45 seconds and occurring on an irregular basis with an average interval between pushes of 13 minutes;
 - b. Quench car movement — an intermittent source emission emanating from the coke in the quench car and lasting

about 15 to 45 seconds, from the end of a coke-even push until the quench car exits from the shed; and

2. Leaking coke-side doors emissions; in the aggregate, the #2 coke-side doors of Battery No. 1 released emissions at a fairly constant rate:

These two emission components — especially the pushing operation — caused the emissions conveyed through the shed exhaust duct to vary widely with respect to particulate concentration, opacity, chemical composition, temperature, and particle size as a function of time.

Since the shed was installed to capture and transport all of the coke-side emissions to a retrofitted control device (not installed at the time of this study), the original testing protocol specified emission tests only in the (induced draft) duct that exhausted the shed. During the tests, however, visibly-significant quantities of particulate emissions were observed leaking from the shed, indicating that the shed's capture and transport efficiency was less than 100 percent. Therefore, the scope of the project was expanded to provide an estimate of the magnitude of these leaks.

Finally, to be fully responsive to the needs and objectives of this test program, a large number of additional, expected^(1,2) air contaminants were measured during this study as shown in Table 1.0-1. The rationale and purposes for sampling each of these materials are given in Table 1.0-2.

The field sampling portion of the study was performed on March 3-7, 1975, after some initial range-finding determinations were made on February 26, 1975. The range-finding determinations included exhaust gas flowrate, moisture content, gas composition

TABLE 1.A-1 GENERALIZED LIST OF ANALYTICAL PROCEDURES

Bessemer Steel Plant
Bethlehem Steel Corporation
Chickadee, Indiana
March 3-7, 1975

Sampling Method	Contaminant	Analytical Method
1. EPA 5 (Final 2a-Bessemer Draft 7-25-74) Modified as per Appendix 5	Particulate a. Acetone-soluble content b. Water-soluble content c. Water-soluble arsenic d. Water-soluble chloride e. Water-soluble chloride f. Water-soluble mercury g. Water-soluble pH h. Water-soluble acidity/alkalinity i. Metals (Ca, Fe, Mg, Pb, Al, Cd, Cu, Mn, Ni, Zn) content j. Total sulfide	EPA 5 (Final 2a-Bessemer Draft 7-25-74) Modified as per Appendix 5 1. Atomic absorption 2. Ion-selective electrode 3. Ion-selective electrode 4. Atomic absorption 5. pH electrode 6. Filtration technique 7. Atomic absorption and voltametric spectrophotometry (Ca, Fe, Cu) 8. Volatile spectrophotometry
2. British Columbia Department of the Environment stack at 4 individual points	Particulate Mass Acetone-soluble content	British Columbia Department of the Environment (specimens) EPA 10/20-70
3. AUSA 10/20-70	Particulate a. Weight measured on No. 10 sieve b. pH c. Acetone-soluble content d. Cyclohexane-soluble content Hydrogen Sulfide Sulfur Dioxide-Hydrogen Acid Mass (as SO ₂) Ammonia	4. Gravimetry 5. pH electrode EPA 11 EPA 8 Ion-selective electrode
4. EPA 11		
5. EPA 8		
6. Absorption in diluted sulfuric acid		

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SECRET 1-8-1 (continued)

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Sampling Method	Concentration	Analytical Method
7. Absorption in sodium hydroxide	Soluble Chlorides Total Sulfates (as SO ₃ ⁻²) Total Solids Insoluble Solids Simple Soluble Cyanide Complex Soluble Cyanide Insoluble Cyanide Total Soluble Phosphates (as P ₂ O ₅) Total Insoluble Phosphates (as P ₂ O ₅) Nitrate + Nitrite (as NO ₃ ⁻)	Ion-selective electrode Visible spectrophotometry Visible spectrophotometry Visible spectrophotometry Ion-selective electrode Ion-selective electrode Ion-selective electrode Ion chromatography Ion chromatography Visible spectrophotometry
8. Adsorption in untreated water	Pyridine Acetone-nitrobenzene Benzene Hexahydro- Benzene	Ion chromatography Ion chromatography Ion chromatography Ion chromatography
9. Grab collection in glass flask	Total Alkaline Hydroxides (as OH ⁻) Methane and Dimethylamine (as CH ₄) Ethylene and Propylene (as C ₂ H ₄) Acetylene Carbon Monoxide	Ion chromatography Ion chromatography Ion chromatography Ion chromatography Ion chromatography
10. Freezing + absorption in cyclohexane	Cyclohexane-soluble content Cyclohexane-insoluble content Phenanthrene Pyrene Chrysene + Benzo[a]pyrene + 1,2,3-trimethylfluorene (as Chrysene) Benzo[ghi]perylene (as benzo[a]pyrene)	Ion chromatography Ion chromatography Ion chromatography Ion chromatography Ion chromatography Ion chromatography
11. Filtration	Filtrate Residues	Gravimetry

Classical Instrumental Studies

TABLE 1.8-2

PURPOSE(S) FOR SAMPLING SATE CONTAMINANT

Borus Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Contaminant	Purpose of Measurement
Particulate	1. Measure particulate emission rate 2. Measure difference between start leakage and pushing operations emissions 3. Obtain data for emission factor for coke-oven battery 4. Measure difference between first half and total particulate
a. Acetone-soluble content	1. Select control device 2. Possible hazardous material 3. Determine organic content 4. Corrosion resistance Standard techniques
b. Water-soluble content	Possible hazardous material
c. Water-soluble atomic	1. Select control device 2. Corrosion resistance
d. Water-soluble chloride	1. Select control device 2. Corrosion resistance 3. Possible hazardous material
e. Water-soluble nmapl; cyanide	Possible hazardous material
f. Water-soluble mercury	Possible hazardous material
g. Water-soluble pH	1. Select control device 2. Corrosion resistance
h. Water-soluble acidity/alkalinity	1. Select control device 2. Corrosion resistance

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TABLE 1.0-2 (continued)

PURPOSE(S) FOR SAMPLING EACH CONTAMINANT

Bessemer Harbor Plant
 Bethlehem Steel Corporation
 Chester, Indiana
 March 3-7, 1975

Contaminant	Purpose of Measurement
1. Metals content (Ca, Fe, Mg, Pb, Al, Cd, Cu, Mn, Se, Zn)	1. Possible hazardous material 2. Standard EPA data-gathering procedure
2. Total sulfate	1. Corrosion resistance 2. Measure sulfate in catch, possible pseudo-particulate
Particle Size	1. Determine particle size distribution 2. Select control device 3. Compare with filterable particulate results
a. Acetone-soluble content	1. Possible hazardous material 2. Compare with particulate catches
Dustfall	1. Measure shed versus non-shed particle fallout (dustfall) 2. Measure dustfall on bench 3. Measure bench versus ground-level dustfall 4. Obtain data for emission factor for coke sizer and battery
a. Weight retained on No. 10 sieve	1. Exclude big chunks of coke 2. Measure shed versus non-shed dustfall
b. pH	1. Select control device 2. Corrosion resistance
c. Acetone-soluble content	1. Possible hazardous material 2. Compare "organics"
d. Cyclohexane-soluble content	1. Possible hazardous material 2. Compare "organics"

TABLE 1.0-2 (continued)

PURPOSE(S) FOR SAMPLING EACH CONTAMINANT

Barns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 1-7, 1975

Contaminant	Purpose of Measurement
Sulfur Dioxide and Sulfuric Acid Mist (as SO_2)	1. Select control device 2. Corrosion resistance 3. Environmental impact
Ammonia	Environmental impact
Soluble Chloride	1. Select control device 2. Corrosion resistance
Total Sulfate (as SO_4^{2-}), Total Sulfate, and Insoluble Sulfate	1. Select control device 2. Corrosion resistance
Simple Soluble Cyanide, Complex Soluble Cyanide, and Insoluble Cyanide	1. Select control device 2. Corrosion resistance 3. Possible hazardous material
Total Soluble Phenolics (as C_6H_5OH) and Total Insoluble Phenolics (as C_6H_5OH)	Environmental impact
Nitrate + Nitrite (as NO_3^{-})	Select control device
Pyridine	Possible hazardous material
Beta-naphthylamine	Possible hazardous material
Benzene and Homologues of Benzene	Possible hazardous material
Total Light Hydrocarbons (as CH_4)	Measure organic emissions
Paraffins and Homologues (as CH_4)	Measure organic emissions
Ethylene and Homologues (as C_2H_4)	Measure organic emissions

Clayton Environmental Consultants, Inc.

TABLE 1.0-2 (continued)
PURPOSE (S) FOR SAMPLING EACH CONTAMINANT

Bessemer Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Contaminant	Purpose of Measurement
Acetylene	Measure organic emissions
Carbon Monoxide	Possible hazardous material
Cyclodextran-soluble content and cyclodextran-insoluble content	Possible hazardous material
Fluoranthene	Possible hazardous material
Pyrene	Possible hazardous material
Chrysene + triphenylene + 1,1,2-benzanthracene (as Chrysene)	Possible hazardous material
Benzo (a) pyrene (as Benzo (a) pyrene)	Possible hazardous material
Positive Radicals	1. Obtain data for emission factor for coke side of battery 2. Evaluate capture efficiency of the shed and the significance of shed leakage
Hydrogen Sulfide	Environmental impact

(during pushing only and also as a continuous or integrated measurement), temperature, and filter obscuration. A list of project participants is given in Table 1.0-3.

Some possible questions and answers that may arise while reading this report are listed in Section 7.0.

TABLE 1.0-3

PROJECT PARTICIPANTS

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1973

U.S. Environmental Protection Agency
Division of Stationary Source Enforcement

Louis R. Paley, P.E., Project Officer
Mark Antell
Bernard Bloom
Don Carey

U.S. Environmental Protection Agency, Region III

Joseph W. Kuns

U.S. Environmental Protection Agency, Region V

R. Edwin Sylvers
Dave Shuls
Paul R. DeFornin
Steve Florin
Nasim Diba

U.S. Environmental Protection Agency
National Enforcement Investigation Center, Region VIII

Dave Broome

U.S. Environmental Protection Agency
Audio Visual Branch

Ron Mitchell
Stanley Gauer

Bethlehem Steel Corporation

G.A. Tramezzer
Robert M. Harvey
Norm D. Hodgson
Tom Kreichelt
John T. Gunn
Carolyn Hance
Ron E. Spalding
Dave Fisher
Gerald Marchant

Phase 7

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AD-516 410 **Inv. 9**

Patented Aircraft Engine and
Airplane Wing, Hagerstown, Md.
POWER REQUIREMENT OF A BLUWING WING WITH
SEALING AND SLATIN TRAILING FLAP
INVEST. BY H. H. HOLMIST, 10 May 50, Rep.
Contract Number 33-5440, 10 May 50, Rep.
(Contract Number 33-5440) UNCLASSIFIED report

Wind tunnel tests on a blowing NACA 00012 airfoil were supplemented by extending the range of flap deflection angles to 9° and by investigating with a sealed flap and with an effective blowing slot width of 0.75 chord, over a range of flap deflection angles from 0° to 70°. The tests were restricted to states of flow where the flow was fully attached to the flap. The comparison of results for the slotted flap with wide blowing slot shows that, at high flap deflection angles, the power requirement of the sealed flap is limited only over a limited range of lift coefficients and is much greater. For higher lift coefficients, the slotted flap is definitely superior.

REID, AUTH: **ONR NA 15** Jun 77

UNCLASSIFIED

1. Flaps - Boundary layer
2. Airfoils - Lift
3. Boundary layer control - Analysis
4. Contract Number 33-5440

Armed Services Technical Information Agency
UNCLASSIFIED

AD-516 585 **Inv. 9**

Patented Aircraft Engine and
Airplane Wing, Hagerstown, Md.
A SAMPLED DATA PROCESSOR, BY H. A. HANCOCK,
10 May 50, Rep. 10 May 50, Rep. 10 May 50, Rep.
(Contract Number 33-5440, 10 May 50, Rep.)
(Contract Number 33-5440) UNCLASSIFIED report

This report describes a semi-automatic data sampler and computer accumulating two channels of information representing optically stored, magnetically stored, or direct electrical data in the form of time varying potentials. All data are converted to time modulated pulses and directed to a computer where a combination of analog and digital computer circuits can be adjusted to perform a variety of mathematical operations on the data with accuracies on the order of 0.1 percent. Results of the computations are displayed numerically on decimal indicators, the registered numbers being proportional to the computed functions (author).

REID, AUTH: **ONR NA 15** Jun 77

UNCLASSIFIED

1. Sampling - Optically stored
2. Sampling - Magnetically stored
3. Sampling - Direct electrical
4. Sampling - Potentials
5. Mathematical computers - Instruction manuals
6. Hancock, H. A.
7. Contract Number 33-5440
8. Contract Number 33-5440

Armed Services Technical Information Agency
UNCLASSIFIED

AD-516 591 **Inv. 9**

Patented Aircraft Engine and
Airplane Wing, Hagerstown, Md.
A METHOD FOR THE ANALYSIS OF FLUID FLOW
IN A BOUNDARY LAYER WITH A FLAT PLATE
INVEST. BY H. H. HOLMIST, 10 May 50, Rep.
(Contract Number 33-5440, 10 May 50, Rep.)
(Contract Number 33-5440) UNCLASSIFIED report

Boundary layer techniques are used to derive, from the full Navier-Stokes equations, and relationships from the full Navier-Stokes equations, for fluids having constant properties. An effort was made to retain validity in the development comparable to that used in previous boundary layer developments. Analytical techniques similar to those employed here were applied to the derivation of equations applicable to fluids having constant and temperature-dependent properties, such as gases. To derive the differential equations for flow in a curved form of arbitrary thickness the use of the

REID, AUTH: **ONR NA 15** Jun 77

UNCLASSIFIED

1. The boundary layer
2. The boundary layer - Mathematical analysis
3. The boundary layer - Mathematical analysis
4. The boundary layer - Mathematical analysis
5. The boundary layer - Mathematical analysis
6. Contract Number 33-5440

Armed Services Technical Information Agency
UNCLASSIFIED

TABLE 1.0-3 (continued)

PROJECT PARTICIPANTS

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Clayton Environmental Consultants, Inc.

Field Team

Richard J. Powals, P.E.	Project Leader
Victor W. Hanson	Senior Environmental Control Specialist
Fred L. Cooper	Group Leader, Source Sampling Studies
Richard G. Keller	Environmental Control Specialist
Richard G. Marcus	Environmental Control Specialist
Richard J. Griffin	Environmental Control Specialist
Gerald E. Hawkins	Environmental Control Specialist
Kent D. Shoemaker	Chemist

Data Analysts

Janet L. Vecchio	Group Leader, Data Processing
Rebecca B. Cooper	Environmental Control Specialist

Laboratory Analysts

Aileen G. Hayes	Assistant Director, Laboratory Services
David J. Holmberg	Laboratory Shift Supervisor
John Knowles	Chemist
Michael D. Kelly	Chemist
Nathan G. Riddle	Chemist
Kent D. Shoemaker	Chemist
James H. McClain	Chemist

Managing Consultant

John E. Hutchler, P.E.	Vice-President, Engineering Services
------------------------	--------------------------------------

2.0 SUMMARY AND CONCLUSIONS

2.1 Coke-Side Particulate Emissions

Two types of particulate emissions were observed to emanate from the coke side of the shed at Battery No. 1 at the Burns Harbor plant of Bethlehem Steel Corporation. These emissions comprised particulate matter discharged through the shed exhaust duct and fugitive particulate matter which escaped the shed. The combination of these two emissions is referred to below as "Overall Continuous Coke-Side Particulate Emissions."

2.1.1 Overall Continuous Coke-Side Particulate Emissions

The overall filterable coke-side particulate emissions ranged from 0.89 to 0.93, and averaged 0.91 pound per ton of dry coal fed to theovens (± 0.06 pound per ton).^{*} These emission measurements inherently include contributions from the following sources: coke-pushing operations (coke pushing and quench car movement), door leaks, and residual particulate concentrations within the shed volume from previous pushes, as well as emissions which escaped the shed. The hourly emission rate corresponding to these emissions ranged from 143 to 151, and averaged 146 pounds per hour (± 10 pounds per hour).

* The notation " ± 0.06 pound per ton" is an estimate of the statistical precision of the average value based upon a 95-percent level of confidence. Although the precision is ± 0.06 , the confidence interval for a concentration, emission rate, or emission factor is always bounded by a minimum value of zero. (See Section 3.10.)

2.1.2 Continuous Particulate Emissions from the Exhaust Duct

Filterable particulate emission measurements made in the exhaust duct evacuating the shed on a continuous basis indicated an average emission factor of 0.78 pound per ton of dry coal fed to the ovens ($\pm$ 0.04 pound per ton). The corresponding average hourly emission rate for continuous particulate emissions was 124 pounds per hour ($\pm$ 10 pounds per hour). These emission measurements inherently include coke-pushing operations emissions, door leaks, and residual emissions from previous pushes, but exclude fugitive emissions.

2.1.3 Peak Particulate Emissions from the Exhaust Duct

Particulate emission measurements made during the initial 3-minute period when pushing emissions were being evacuated from the shed (heaviest visible emission period) indicated an average emission factor of 0.64 pound of filterable particulate per ton of dry coal charged to the ovens ($\pm$ 0.34 pound per ton). The corresponding emission rate for this period averaged 93.2 pounds of filterable particulate per hour ($\pm$ 47.9 pounds per hour). It should be noted that because of the frequency and overall duration of sampling, the emission rates for these peak emissions have been adjusted to reflect typical operations; i.e., 4.9 pushes per hour. In addition, these values inherently include door leaks and residual emissions from previous pushes, but exclude fugitive emissions.

2.1.4 Fugitive Particulate Emissions from the Shed

The fugitive particulate emissions from the shed occurred at four positions: The north and south ends of the shed, the Askania valves, and the boundary between the shed and the coke battery. On a continuous basis, these (filterable) fugitive emissions were estimated to average 0.14 pound per ton of dry coal fed to the ovens, or 21.9 pounds of fugitive particulate per hour. Related to the continuous filterable particulate emissions, they averaged 15 percent of the overall emissions.

2.1.5 Particulate Emissions for Pushing Operations

Using the particulate emissions data presented previously and a straightforward calculational procedure, it was possible to obtain a rough estimate of the particulate emissions attributable to pushing operations alone at the Burns Harbor plant. These emissions were estimated to average 0.59 pound of filterable particulate per ton of dry coal fed to the ovens ($\pm$ 0.51 pound per ton). This emission factor has been adjusted to include fugitive emissions from the shed.

2.1.6 Particulate Emissions for Non-Pushing Operations

The overall coke-side emissions for non-pushing operations were roughly estimated to average 0.22 pound of filterable particulate per ton of dry coal fed to the ovens ($\pm$ 0.46 pound per ton). This factor has been adjusted to include fugitive emissions.

Using these data, pushing operations were found, on an average basis, to account for 76 percent of the overall coke-side particulate emissions, while 24 percent were attributable to non-pushing operations.

2.2 Shed Particulate Capture Efficiency

Because significant visible fugitive emissions were observed escaping from the shed during the study, and in order for EPA to evaluate the cost-effectiveness of the shed concept, it was necessary to evaluate the particulate capture efficiency of the shed.

2.2.1 Evaluation of Shed Capture Efficiency

The efficiency of the shed in capturing and exhausting coke-side emissions from pushing (based upon particulate emission measurements) was found to be approximately 85 percent. Thus, on a "continuous" basis, an average of 15 percent of the particulate emissions escaped from the shed.

2.2.2 Possible Causes of Leakage

Several potential causes for the existence of fugitive particulate emissions have been suggested. These include the following:

1. The overall magnitude of the shed's holding volume appeared to be too small relative to the magnitude of the emissions, and the effective exhaust rate of the shed may have been too low;
2. It is possible that "short circuiting" of the outside air to the exhaust duct occurred; and
3. The shape, size, and location of the holding

chamber and/or the exhaust duct, as well as the shed wall and end openings, may have affected the capture efficiency of the shed.

2.3 Chemical Composition of Particulate Emissions

The particulate matter samples taken during this study were subjected to 19 separate analyses to determine particulate composition. The results indicated that the particulate matter was predominantly carbonaceous with undetectable or trace amounts of nearly all other constituents for which analyses were performed.

2.4 Particle Size Distribution

The size distribution of particulate matter varied greatly as a function of sampling position in the exhaust duct, probably due to the numerous changes in direction of the exhaust gas flow within the duct. On an average basis, however, approximately 32 percent of the particulate was smaller than seven microns and approximately seven percent was smaller than one micron.

2.5 Emissions of Other Materials

In addition to particulate, sampling was conducted to determine the concentration of 29 other potential air contaminants from coke pushing. Cyclohexane solubles and insolubles, ethylene and homologues, and total light hydrocarbons were found to be discharged at emission rates exceeding 100 pounds per hour. All other measured contaminants were detected at levels that averaged less than 10 pounds per hour.

2.6 Dustfall Measurements

Dustfall measurements were taken within the shed on Battery No. 1 and at similar locations on the adjoining unshedded but

generally-comparable battery. The purpose of these measurements was to assess the shed's effect on dustfall rate at employee work stations.

For three of the four locations considered, dustfall (settlicable particulate) rates beneath the shed were statistically greater than those at corresponding locations in the unshaded No. 2 Battery. The dustfall at the bench location, the primary work station, did not differ between the two batteries. As expected, greater dustfall rates were experienced at the No. 1 Battery near the shed wall than at locations nearer the bench. Thus, the shed's design effectively causes the increased quantity of dustfall to drop away from the work stations to a location near the wall of the shed.

2.7 Indices of Visible Emissions

2.7.1 Degree of Greenness

The average value for the degree of greenness of the pushed coke (product of the sum of the greenness ratings and the duration of the push) ranged from 222 to 285 for the three particulate sampling periods. The third particulate sampling period was found to contain pushes of higher greenness ratings than the other two sampling periods.

2.7.2 Opacity

Opacity data were acquired for the two stacks discharging emissions from the shed exhaust duct during the study. For the 3-minute "peak" periods during particulate sampling, the average opacity was found to range from 40 to 60 percent. The third particulate sampling period

resulted in an average opacity which exceeded that of the other two sampling periods.

2.7.3 Percent of Doors Leaking

For particulate sampling days, coke-side oven door leakage was found to vary from 27 to 69 percent on Battery No. 1 and from 39 to 64 percent on Battery No. 2. Push-side door leakage for both batteries was found to be less than that of coke-side door leakage and was less variable.

2.8 Process and Emissions Correlations

Linear correlation techniques were attempted but revealed no significant relationships between the continuous filterable particulate emission factors or the filterable particulate push-only emission factors and average degree of greenness or average opacity. Further, no statistically significant relationships were found between continuous filterable particulate emission factors and net coking time or average flue temperature. The small sample size, however, limited the sensitivity of the statistical analyses in these cases.

For the particle sizing samples, no linear correlation was apparent between variations in size distributions for each of the samples and the greenness of the push. In addition, no significant correlation was apparent between particle size and net coking time. Again, however, the small sample size limited the sensitivity of the statistical technique.

Both peak opacity and greenness were found to be very highly correlated with net coking time, minus a constant of 1000 minutes, when the reciprocal of each of the values was used. In

addition, peak opacity and greenness were each very highly correlated with flue temperature.

A highly significant statistical relationship was apparent between the degree of greenness and the opacity of the exhaust duct emissions. This relationship characterized opacity as a function of the logarithm of greenness.

3.9 Representativeness of Process and Shed Conditions

In order to document that the measured results were representative of Battery No. 1's actual emissions during normal production, six criteria for comparison were established. On the basis of these criteria, all samples obtained during this study were found to be taken during generally representative process and shed conditions. Only three minor deviations from the criteria were observed during the more than 300 observations used to establish representativeness.

3.0 PROCESS DESCRIPTION AND OPERATIONS

3.1 Process Description

Bethlehem Steel Corporation operates a by-product metallurgical coke manufacturing facility at its Burns Harbor plant in Chesterton, Indiana. This operation includes a destructive distillation process, generally termed "coking," that occurs when coal is heated in an atmosphere of low oxygen content. By-product organic compounds, generated during the coking, are recovered from the coke-oven off-gases. The main product, de-gasified coal, commonly known as "coke," is a critical raw material used in the production of iron.

The by-product coking process occurs in a "coke battery," a series of contiguous, rectangular, refractory-lined ovens. At the Burns Harbor plant, two coke batteries, each containing 82 ovens, are positioned end-to-end (See Figure 3.1-1). Each oven, 20 feet tall, 18 inches wide (average width; the oven is actually tapered), and 30-feet long, is capable of producing about 24.5 tons of coke per push. At the beginning of a coking cycle, coal is charged (dumped) through ports in the top of each oven. Subsequently, each port is sealed and heat is applied to the oven to maintain a temperature of 2100 to 2450°F. About 18 hours later, at the end of the coking cycle, the incandescent coke is pushed from the oven with a mechanical ram into a specially-designed railroad car, called a "quench car." The load of hot coke in the quench car is subsequently flooded with water at the quenching station.

The large number of ovens on each battery makes it possible to average 4.5 pushes per hour, utilizing the same equipment for

—•—

Push Side

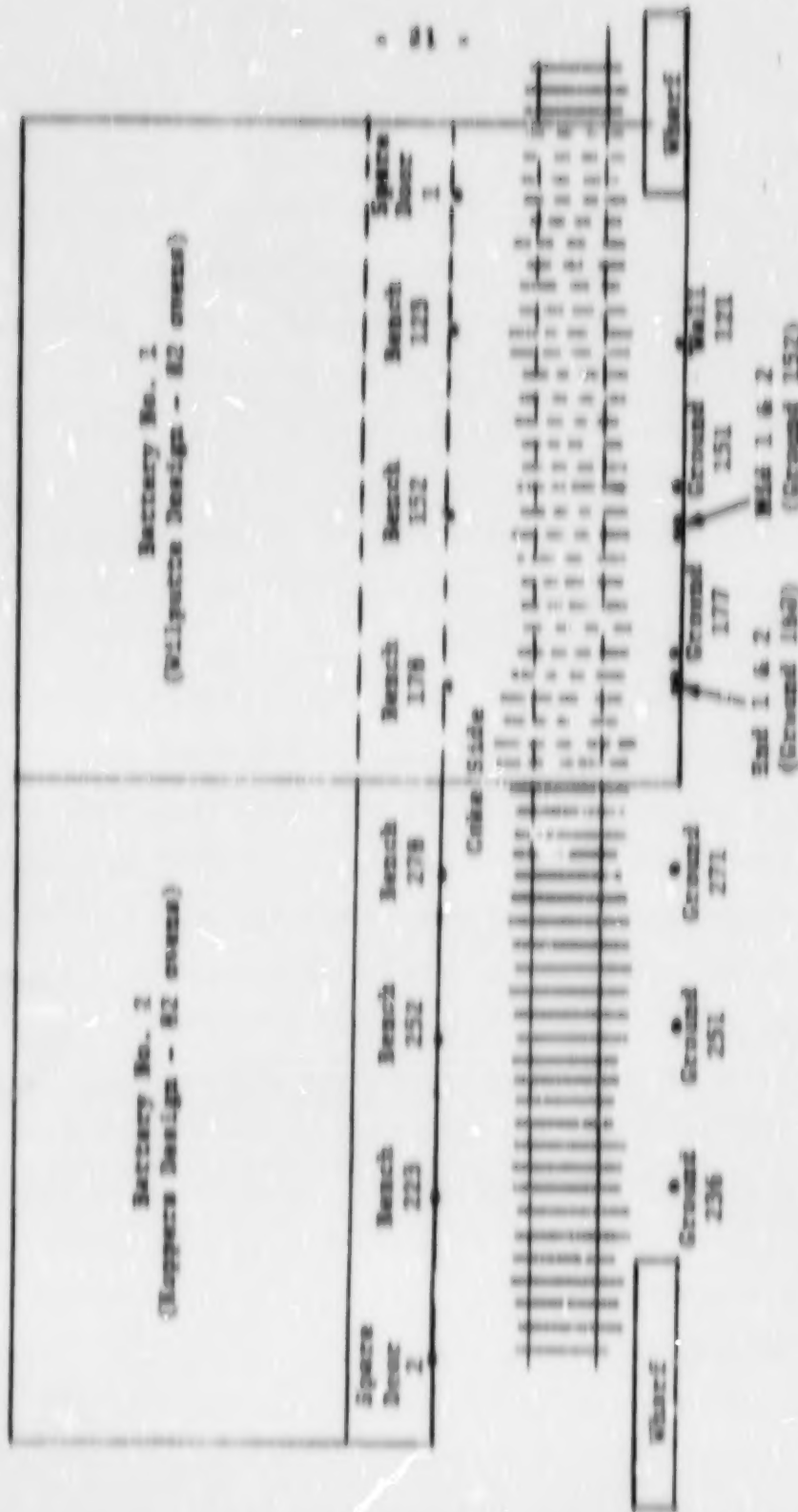


FIGURE 3.1-1

SCHEMATIC DIAGRAM OF RE-product, METALLURGICAL COKE MANUFACTURING FACILITY
WITH DUSTFALL SITES

Burns Harbor Plant
Bethlehem Steel Corporation
Chester, Indiana
March 3-7, 1975

Clayton Environmental Consultants, Inc.

charging the coal to each oven. During the coking cycle, the oven is sealed on both ends with refractory-lined doors which are locked into place just prior to oven charging. The doors are then removed just prior to pushing the coke from the oven.

Emissions from the coke ovens can occur throughout the cycle from around the sealed doors ("door leaks"), as well as at the end of the cycle when the coke is pushed from the oven ("pushing"). The duration of the coke pushing operations phase of the oven cycle is brief, lasting about 45-90 seconds (approximately 30 seconds for coke-pushing emissions and 15 to 60 seconds for quench car movement emissions). Nevertheless, emissions during this brief period can be very copious.

The emissions generated from the coke side of Battery No. 1 at the Burns Harbor plant from door leakage and coke pushing are predominantly captured by a semi-enclosed structure termed the "shed." A schematic of this enclosure is presented in Figure 3.1-2. The shed is designed to capture these emissions, which exhibit significant thermal rise, and exhaust them through the duct located at the shed's apex. This mechanically-exhausted, coke-side shed is a canopy-type hood that is about 400 feet long and encloses a volume of about 225,000 cubic feet. Despite the design, fugitive emissions escape this enclosure on both ends, as shown in Figures 3.1-2 and 3.1-3. The source testing performed during this project was designed to measure total coke-side emissions. Therefore, measurements were made of the emissions collected and exhausted through the duct as well as the fugitive emissions from the shed. These fugitive emissions were documented as they related to coke battery and shed operating parameters. Additionally, the study documented

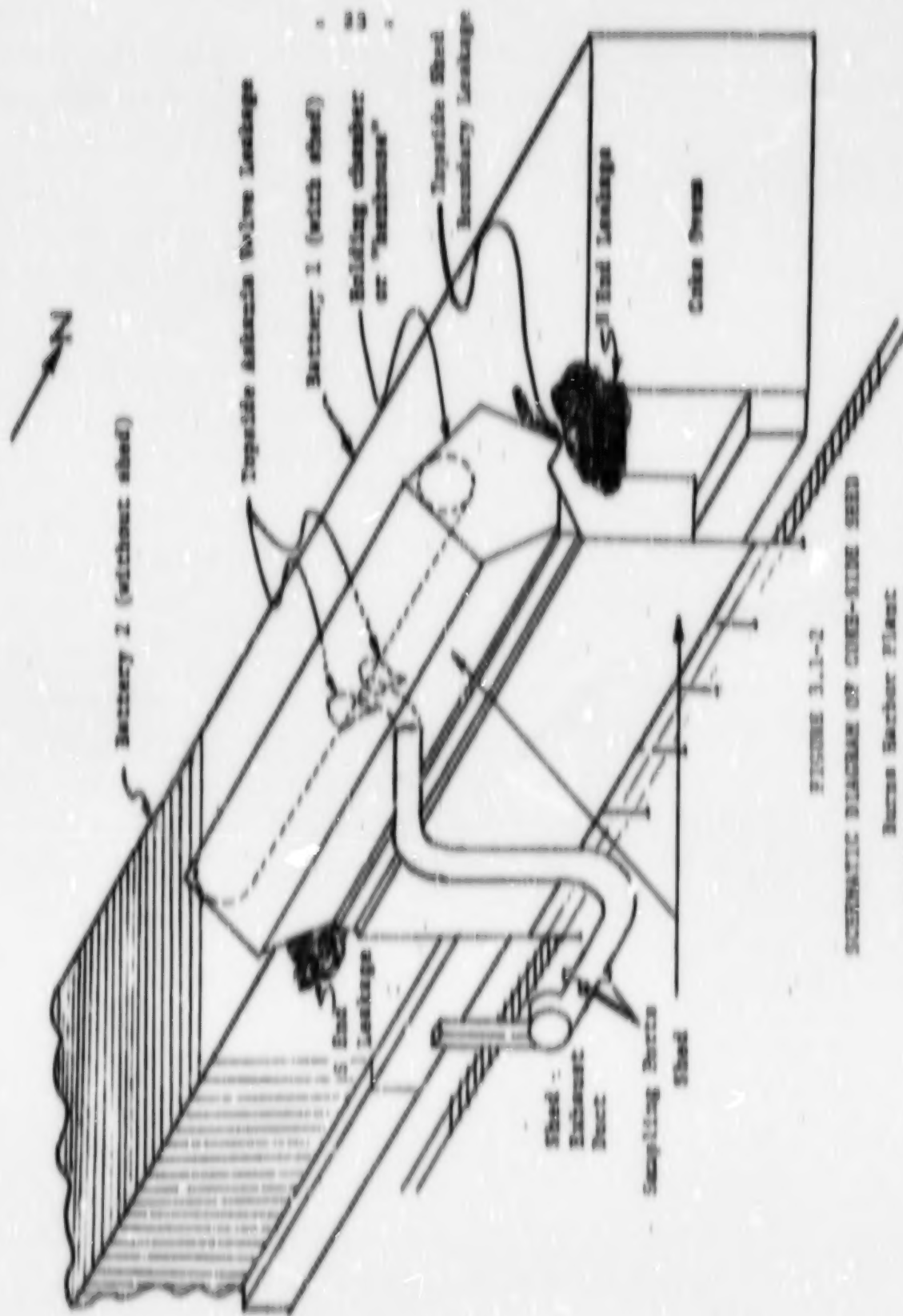


FIGURE 3.1-2

SCHEMATIC DIAGRAM OF COKE-SIDE SHED

Burns Harbor Plant

Nuclease Steel Corporation

Chesterton, Indiana

March 3-7, 1975

Clayton Environmental Consultants, Inc.

South End

North End

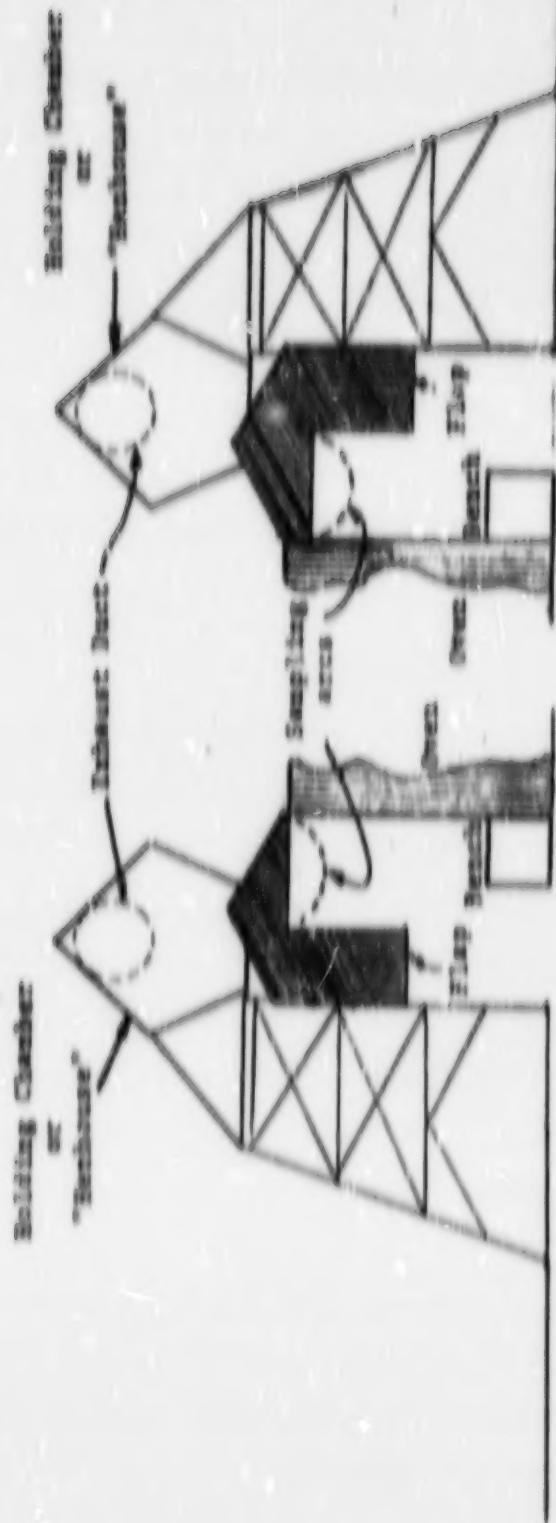


FIGURE 3.1-3

SCHEMATIC DIAGRAM OF CURB-TIME USED AND OPENINGS

Reiss Barber Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Clayton Environmental Consultants, Inc.

the "dustfall" rates within the shed and at similar positions on the unshedded Battery No. 2 (see Figure 3.1-1).

3.2 Representativeness of Process and Shed Conditions

Because it cannot be assumed (without documentation) that measured results are representative of the actual emissions of a source, it was necessary to: (1) define thoroughly the objective(s) of the test program prior to developing the test protocol; (2) identify specifically the process, control device, test, and analytical conditions required to achieve the objective(s); (3) define, in advance of testing, the acceptable range for each parameter; and (4) document that the required conditions were maintained during the test period.

3.2.1 Criteria for Comparison

Before the results presented in this report could be considered representative of non-test period operations, it was necessary to document that all relevant process and operational conditions for test and specific non-test periods were acceptably "similar." The criterion for acceptably similar data was arbitrarily defined as ± 10 percent of the average typical operating conditions.

Further, to more clearly define the terminology regarding coke-pushing operations, the following definitions were formulated:

Atypical operating conditions: extremely infrequent major process changes (or upsets).

Typical operating conditions: any process operating conditions not atypical.

Abnormal operating conditions: any typical operating conditions during which net coking time is outside the normal net coking time or during which any coke-pushing stoppage greater than 30 minutes duration occurs.

Normal operating conditions: any typical operating conditions not abnormal.

Therefore, "abnormal" and "normal" operating conditions are complementary subsets within the category "typical" operating conditions.

After a preliminary assessment of the parameters given in Table 3.2.1, it was determined that some of the process variables were nearly constant (Askan's valve pressure, average daily oven cross-wall temperature, etc.) while many others (such as net coking time) were not constant with time. Additionally, based upon the effect of a given parameter upon the shed exhaust duct opacity and the particulate emission rates reported from earlier source tests at other coke-oven facilities, Mr. Paley (U.S. EPA) and Mr. Powell (Clayton Environmental Consultants, Inc.) decided to limit the testing of the battery's coke-side emissions to periods when the conditions were maintained within the ranges given below:

1. Net coking time of 17-1/4 to 18-1/2 hours (1035-1110 minutes),
2. Coke-pushing cycle duration up to 30 minutes long (within $\pm$ 10 percent),
3. Coal feed rate of 35 tons (wet) per charge (within $\pm$ 10 percent);

TABLE 3.2.1
PERTINENT PARAMETERS
Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Coking Time (minutes)

Net
Minimum

Average Daily Gross-Wall Temperatures ("F)

Gas

Feed rate (wet pounds charged per oven)
Feed rate (dry pounds charged per oven)
Chemical and physical analyses (average values)

Average Underfire Gas Flow (10^3 CFH)

Coke

Average rate of production (tons per day)
Physical analyses (average values)

Coke Oven Gas

Average rate of production (10^3 CFH)
Chemical analyses

Average Arsenic Valve Pressure (mm H₂O)

Battery Operations

Number and location of empty ovens
Door maintenance
Scheduled/unscheduled downtime
Use of experimental doors
Occurrence of atypical or abnormal events

Coke-Pushing Operation

Clock time for each oven pushed
Duration of each push (seconds)
Duration of each push cycle (minutes)
Greenness of coke-oven push

Shed Evaluation

Average exhaust rate (actual cubic feet per minute)
Fan curves
Amperage and voltage used
Duration required to clear the peak (push) emissions

Oven Door Leak Observations

Coke side
Push-side and chuck doors

Local Surface Wind Conditions

Average speed (mph) and direction (degrees) during test period
Speed (mph) and direction (degrees) during non-test period
Persistence at 45° and $\pm$ 6 mph of winds

Shed Design Parameters (size, shape)

4. Coke production rate of 24 tons per push (within ± 10 percent);
5. Average pushing rate of 4.5 pushes per hour (within ± 10 percent);
6. Coal analysis (average percent coal moisture and BTU/lb coal) comparable to that of typically charged coal (within ± 10 percent); and
7. Shed evacuation rate of 300,000 SCFM (within ± 10 percent).

3.2.2 Conditions during Sampling Periods

On the basis of the criteria presented in Section 3.2.1, all samples obtained during this study were taken during generally representative process and shed conditions by interrupting sampling during abnormal and atypical periods. Tables 3.2.2-1 and 3.2.2-2 indicate the average values and the range of values for each of the six criteria discussed previously for periods before, during, and after particulate sampling. Exceptions to the first of the six criteria occurred on the two occasions when Oven 191 was pushed, i.e., during Particulate Tests 1 and 3. The net coking time for this oven was approximately 1400 minutes due to its position at the end of the battery; this is typical for Oven 191. There was also a single exception to the second criterion during Particulate Test No. 2, when a 39-minute interval between pushes occurred. These three observations were the only deviations, however, from the six criteria (encompassing over 300 observations)

TABLE 3.2.2-1
COMPARISON OF KEY PROCESS PARAMETERS
(BATTERY NO. 1)

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Parameter	Time Period				
	Before Sampling		During Continuous Particulate Sampling	After Sampling	
	All Data	All Typical* Data		All Data	All Typical* Data
Average Hot Coking Time (minutes)	1096	1076	1071	1073	1071
Range of Time Between Pushes (minutes)	3-103	3-99	7-39	8-93	8-93
Average Time Between Pushes (minutes)	13	13	12	13	13
Average Wet Coal Feed Rate (tons/charge)	**	**	35.0	34.8	34.8
Average Coke Production Rate (tons/push)	**	**	25.6	25.4	25.4
Average Number of Pushes/hour	4.4	4.9	4.9	4.9	4.9
Average Coal Moisture Content (percent)	6.7	6.6	5.9	7.3	7.3
Average BTU/lb Coal	1162	1160	1160	1166	1166
Average Shed Evacuation Rate (DSCFM)	295,000 (BSC Data)		268,000	---	

* Typical data is all data other than that for which five (4.9 ± 10%) or more consecutive hot coking times were outside of the range of 17-1/4 to 18-1/2 hours, i.e., 1035 to 1110 minutes.

** information requested but not received.

TABLE 3.2.2-2

COMPARISON OF KEY PROCESS PARAMETERS
(BATTERY NO. 2)

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1976

Parameter	Time Period		
	Before Sampling	During Sampling Days (March 3-7, 1976)	After Sampling
Average Hot Coking Time (Minutes)	1028	1003	1003
Range of Time Between Pushes (Minutes)	4-132	6-96	9-66
Average Wet Coal Feed Rate (Tons/Charge)	34.8	35.0	35.3
Average Coke Production Rate (Tons/Push)	25.4	25.6	25.8
Average Number of Pushes/hour	4.8	4.9	4.9
Average Coal Moisture Content (Percent)	6.7	6.9	7.3
Average BTU/lb coal	1281	1287	1287

established for representative sampling.

The intent to ensure that these tests were representative of typical operations at the maximum production rate required the sampling to be delayed several months during a coal strike until the plant had been at typical operating conditions for at least one week. Two days before the scheduled initiation of the emission tests, the plant incurred a major upset (coal feed conveyor breakdown) which caused a few additional days of atypical operating conditions. This resulted in a second delay in the test schedule. A third delay occurred when, after a preliminary traverse, the stack gas exhaust rate was found to be somewhat under the criterion mentioned in Item 7 above. However, after assurances were given by Bethlehem Steel Corporation personnel that the exhaust rate was at maximum and representative conditions, sampling commenced. During sampling, the stack gas exhaust rate was nearly within the ± 10 percent criterion. A few plant equipment problems did cause abnormal operations during the test period. However, since the effects of such irregularities passed rapidly, the response to such events was only to interrupt the tests until the process and shed conditions were again operating normally.

The procedure used to ensure these representative process and shed conditions included documenting, by comparison to data from other operating periods, the fact that the sampling period was representative of typical operations. All process operations and shed performance data acquired for the sampling period and for periods prior to and following the sampling period are provided in Appendices A-D (Volumes 2-4).

3.3 Identification of Possible Normalizing Factors

Source sampling and analytical data must frequently be normalized using process or performance data to obtain a more representative characterization of emissions due to varying operational conditions. Prior to, during, and subsequent to this study, potentially significant process, shop, meteorological and emission data were obtained and recorded by both Bethlehem Steel Corporation and EPA personnel. Those parameters considered as possible normalizing factors were given in Table 3.2.1.

Two rationales were considered in the selection of a normalizing factor:

- a. Emission data should be normalized with reference to some process parameter to reflect the average (or "normal") particulate emission rate.
- b. Emission data should not be normalized with reference to some process parameter to reflect the maximum emission rate (assuming continuous pushing and not just one push about every 15 minutes).

To reflect actual operating conditions, the first of these two alternatives was chosen. Further, and traditionally, emission rates have been compared and normalized to the process input rate, based in part upon the concept of a material balance. Finally, in this case the process input rate (coal feed rate) is a directly measurable quantity. Thus, particulate emissions data have been normalized with respect to coal feed rate to facilitate interpretation of the particulate emissions data. Such normalized particulate emission rates are presented in sections 2.0 and 5.0.

4.0 SAMPLING AND ANALYTICAL METHODS

4.1 Test Protocol

In general, the sampling, sample handling, calibration, and analyses performed in this study incorporated the latest, most well-established methods available, including those promulgated by EPA and ASTM. There were several instances, however, as described in subsequent paragraphs, when modified or novel techniques were required in order to ensure representative results. In all cases, a method was selected only if it satisfied the following criteria-questions:

1. Would the sampling procedure quantitatively catch the analyte of interest?
2. Would the analyte of interest be caught in a medium or media in which it could be separated and quantified?
3. Would the analytical procedure characterize all of the contaminant species of interest while minimizing the necessary number of tests?

This study was designed to investigate thoroughly the typical, normal emissions produced on the coke side of Battery No. 1, including any fugitive emissions that might occur. Thus, the approach to meeting this objective was to define both the process conditions and sampling and analytical methods required to measure the emissions during typical, normal operation conditions. Sampling and analytical procedures were therefore specifically designed around the process and capture system characteristics to provide the maximum amount of information with a reasonable expenditure of effort. Additionally, much

care was taken to ensure that sampling occurred only during "normal" operations (as agreed mutually by Bethlehem Steel personnel and Messers. Bloom and Paley of the DSEE, U.S. EPA; see Section 3.2).

After initial discussions with persons from Bethlehem Steel Corporation and Clayton Environmental Consultants, Inc., it was mutually agreed that the U.S. EPA would be responsible for acquisition of all process data from Bethlehem Steel Corporation while Clayton Environmental Consultants would be responsible for acquisition of the sampling and analytical information. The EPA was also responsible for visible emissions data acquisition, including still and motion photography. Accordingly, the three parties (Bethlehem Steel Corporation, Clayton Environmental Consultants, and the U.S. EPA) worked closely together to acquire the information necessary to document the results of this study. The types of process data acquired were reviewed in Table 3.2.1 (and are presented in Volumes 2 through 4); while the types of sampling and analytical data acquired were given in Table 4.0-1.

4.2 Location of Sampling Points

"Continuous" particulate sampling was conducted in the shed exhaust duct shown in Figure 3.1-2. The sampling plane location and sampling point locations met the minimum requirements specified in "Method 1 - Sample and Velocity Traverses for Stationary Sources, U.S. EPA, In-house Draft, 7-18-74" (Appendix P, Volume 3). The sampling plane was located 3.2 duct diameters downstream of the nearest potential disturbance

and 1.2 duct diameters upstream of the stacks. The two sampling ports were located 90 degrees apart in the circular duct. The duct was subdivided into 48 equal areas; the 48 sampling points are shown in Figure 4.2-1.

Peak particulate sampling was conducted through the same two ports used for continuous particulate sampling. In order to avoid probe crossover, however, while obtaining continuous and peak samples concurrently, the duct was subdivided into 20 equal areas for peak particulate sampling. The 20 peak sampling points are shown in Figure 4.2-2.

Each of the four particle-sizing samples was taken at a single sampling point accessed through the horizontal port. These four tests are identified in the summary tables and graphs by the sampling-point numbers shown in Figure 4.2-3.

All other samples, such as sulfur oxides and samples collected in sodium hydroxide, were taken at a single point 30 inches into the duct through the top port. This sampling point is indicated in Figure 4.2-3.

4.3 Continuous Particulate Emissions from Shed Exhaust Duct

"Continuous" particulate sampling was conducted to obtain an estimate of the "continuous" particulate emissions from the coke-side shed and included coke-pushing operation emissions, door leaks, and residual emissions from previous pushes. These samples were taken by sampling continuously except when operational upsets or downtime occurred of greater than 30-minute duration.

Continuous particulate sampling was conducted in accordance with the then-most-recent drafts of EPA Methods 1, 2, and 5

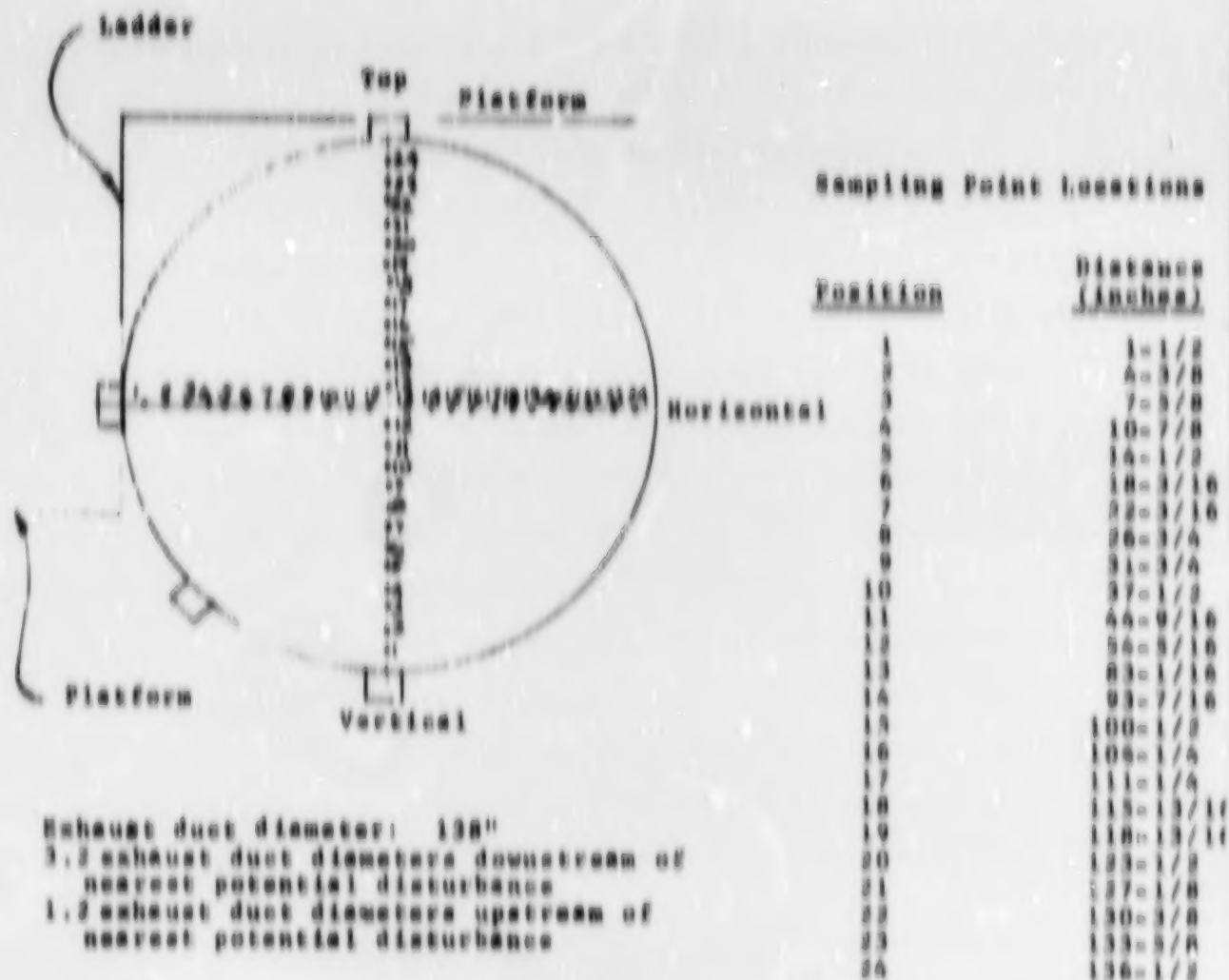
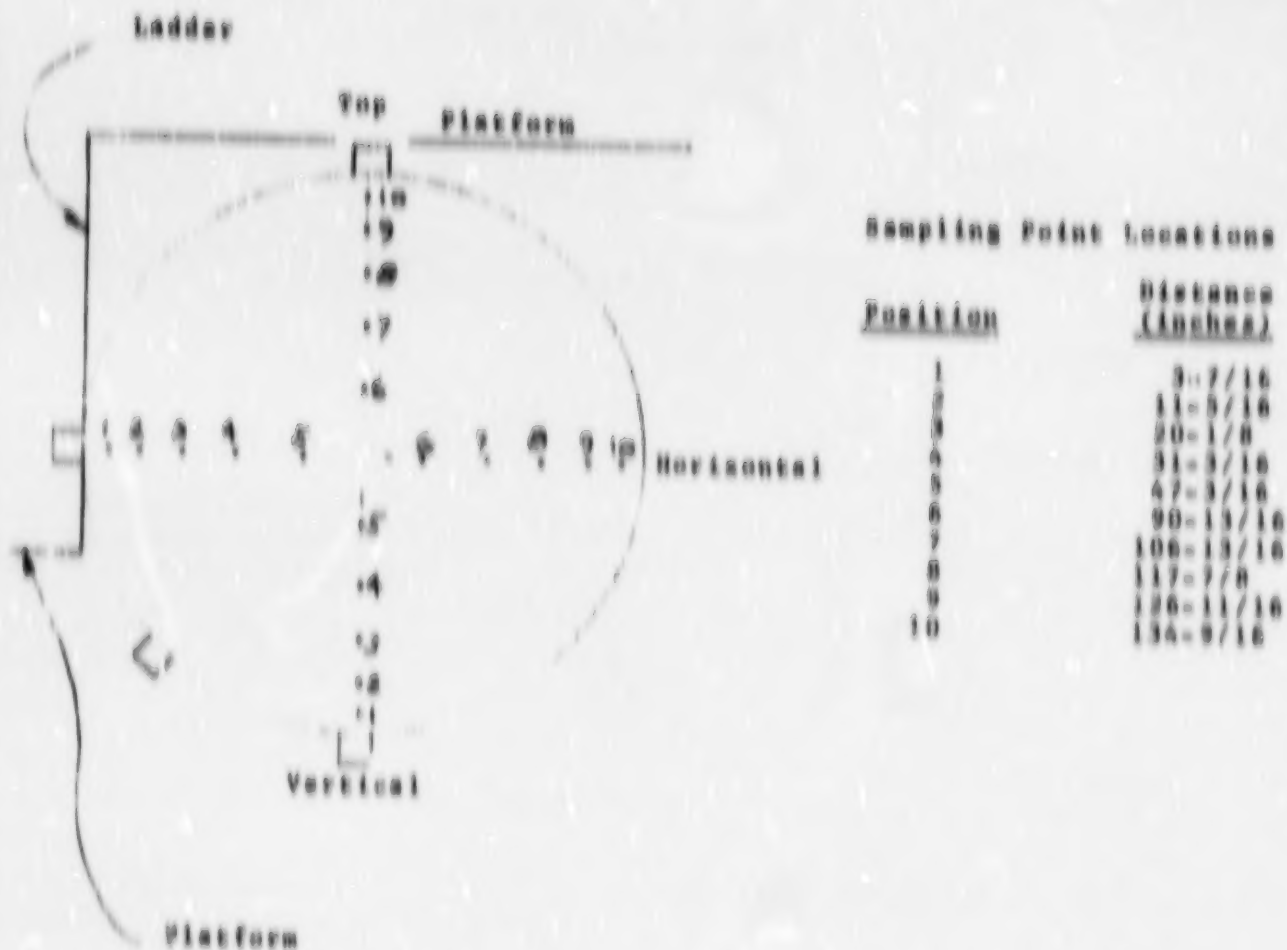


FIGURE 4.2-1

SCHEMATIC DIAGRAM OF SAMPLING POINT LOCATIONS
FOR "CONTINUOUS" PARTICULATE SAMPLES

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975



Exhaust duct diameter: 138"

3.2 exhaust duct diameters downstream of nearest potential disturbance

1.2 exhaust duct diameters upstream of nearest potential disturbance

FIGURE 4.2-2

SCHEMATIC DIAGRAM OF SAMPLING POINT LOCATIONS
FOR "PEAK" PARTICULATE SAMPLES

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1973

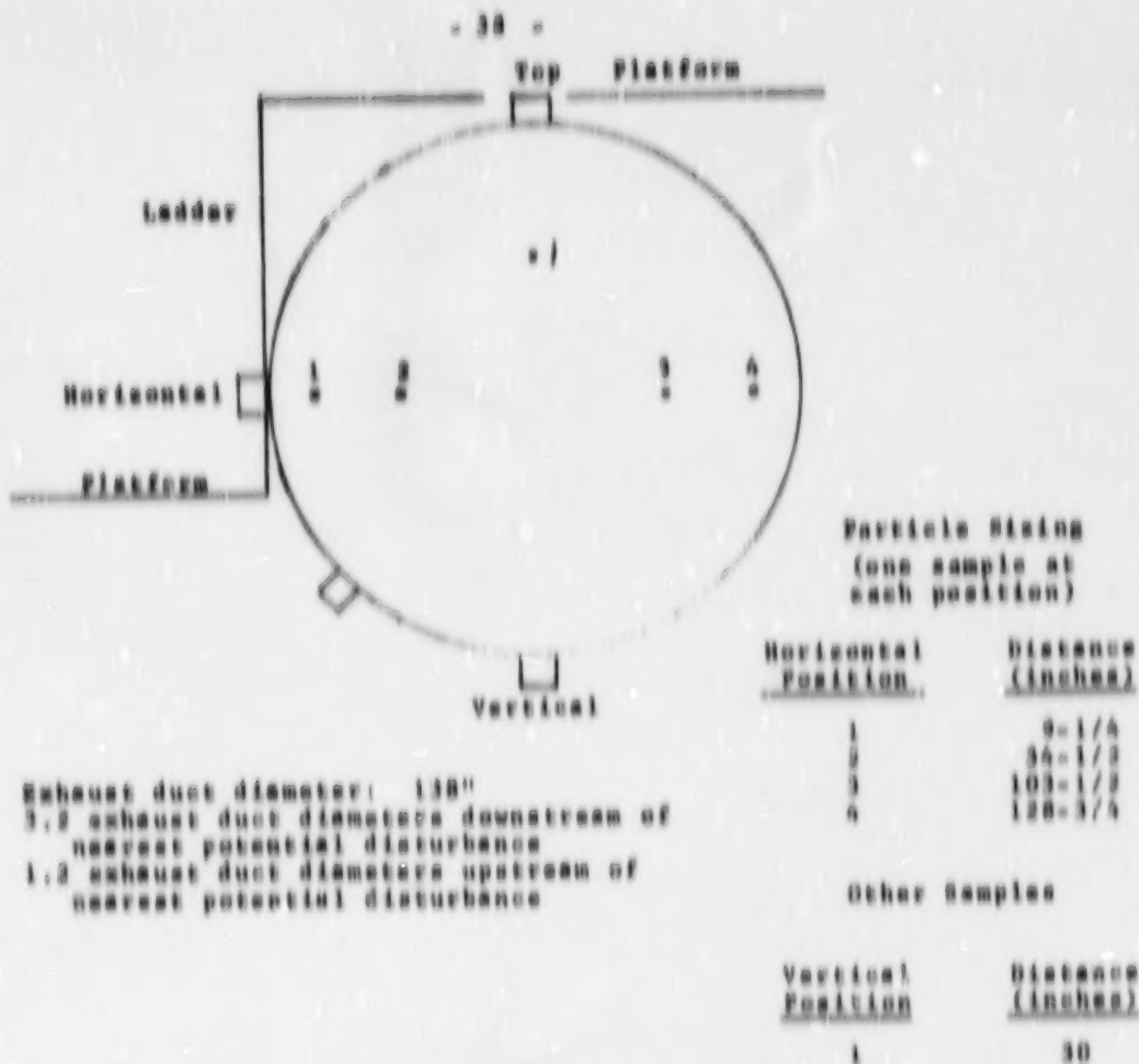


FIGURE 4.2-3

SCHEMATIC DIAGRAM OF SAMPLING POINT LOCATIONS
FOR ALL SAMPLES EXCEPT PARTICULATE

Burns Harbor Plant
Bethlehem Steel Corporation
Chasterton, Indiana
March 3-7, 1973

(Final in-house Drafts 7-18-74, 7-21-74, and 7-25-74, respectively). Copies of these methods are presented in Appendices F-H, respectively (Volume 3). It should be noted that this draft of EPA Method 5 allows the filter in the sampling train to be maintained at a temperature other than "about 250°F" and also allows measurement of the impinger catch. Because no change in particulate concentration was anticipated by sampling at any temperature up to that of the stack gas, the temperature of the filter for the continuous particulate tests was maintained at the average stack gas temperature, which ranged from 84 to 98°F. Detailed descriptions of the sampling and analytical methods are given in Appendix 8 (Volume 3). The particulate samples were analyzed for the materials indicated in Table 1.0-1.

4.4 Determination of Peak Particulate Emission Period

This study was designed to independently measure both the continuous particulate emission rate and the intermittent particulate emission rate during the coke-pushing operation, i.e., peak particulate emission rate. To ascertain the average duration of the period of peak particulate emissions from the exhaust duct, two sets of filter obscurity, opacity, and temperature measurements were acquired. These data are presented in Figures 4.4-1 and 4.4-2 and Table 4.4. The times indicated on Figures 4.4-1 and 4.4-2 represent the time interval since the beginning of the push during which the sample was taken. Evaluation of these data indicates that the peak particulate emission period was approximately three minutes. The method of data analysis is described in detail in Appendix T (Volume 3).

FIGURE 4.4-1

SEQUENTIAL FILTER OBSOURITY TEST ON FEBRUARY 24, 1975

Buena Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

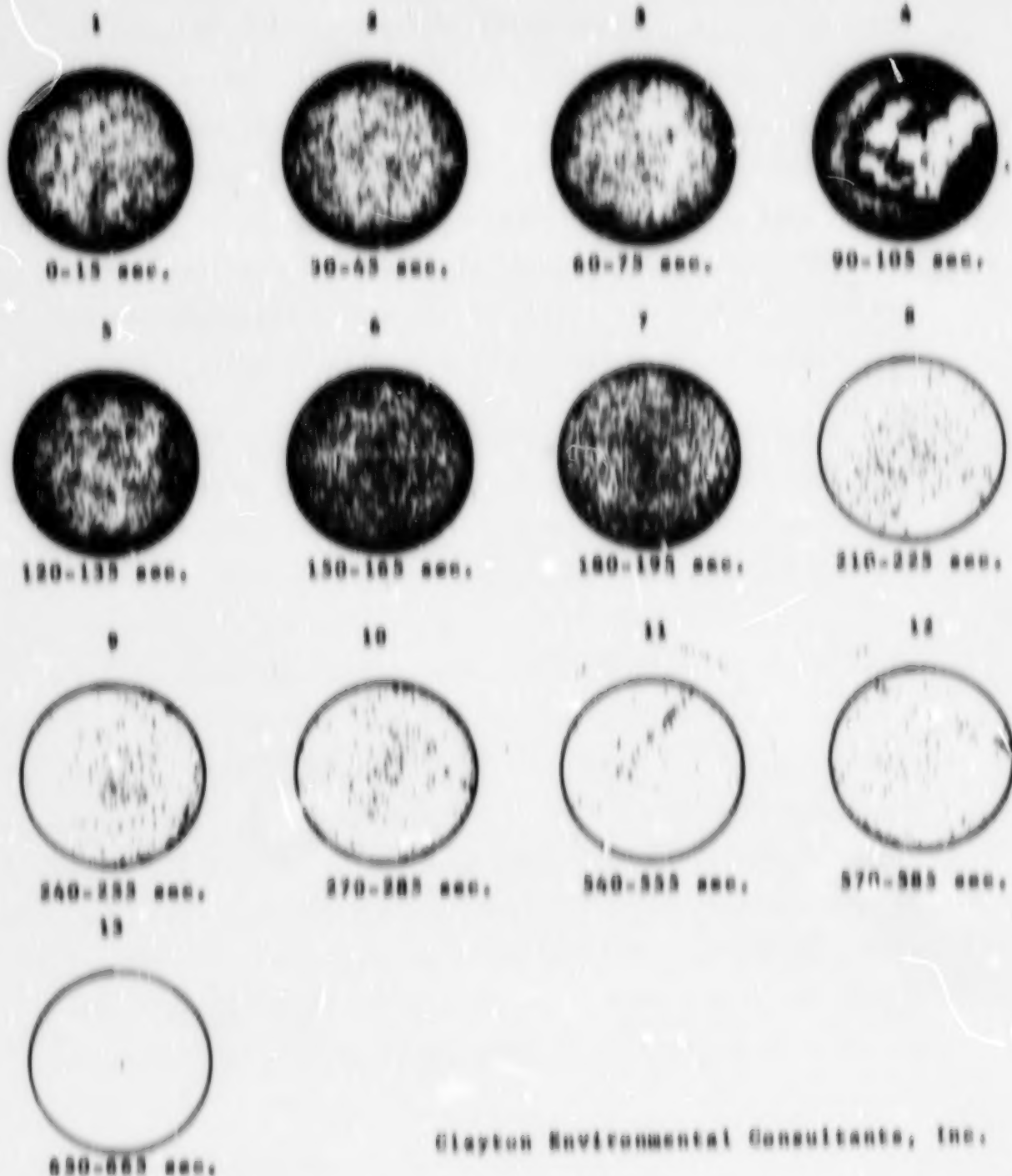
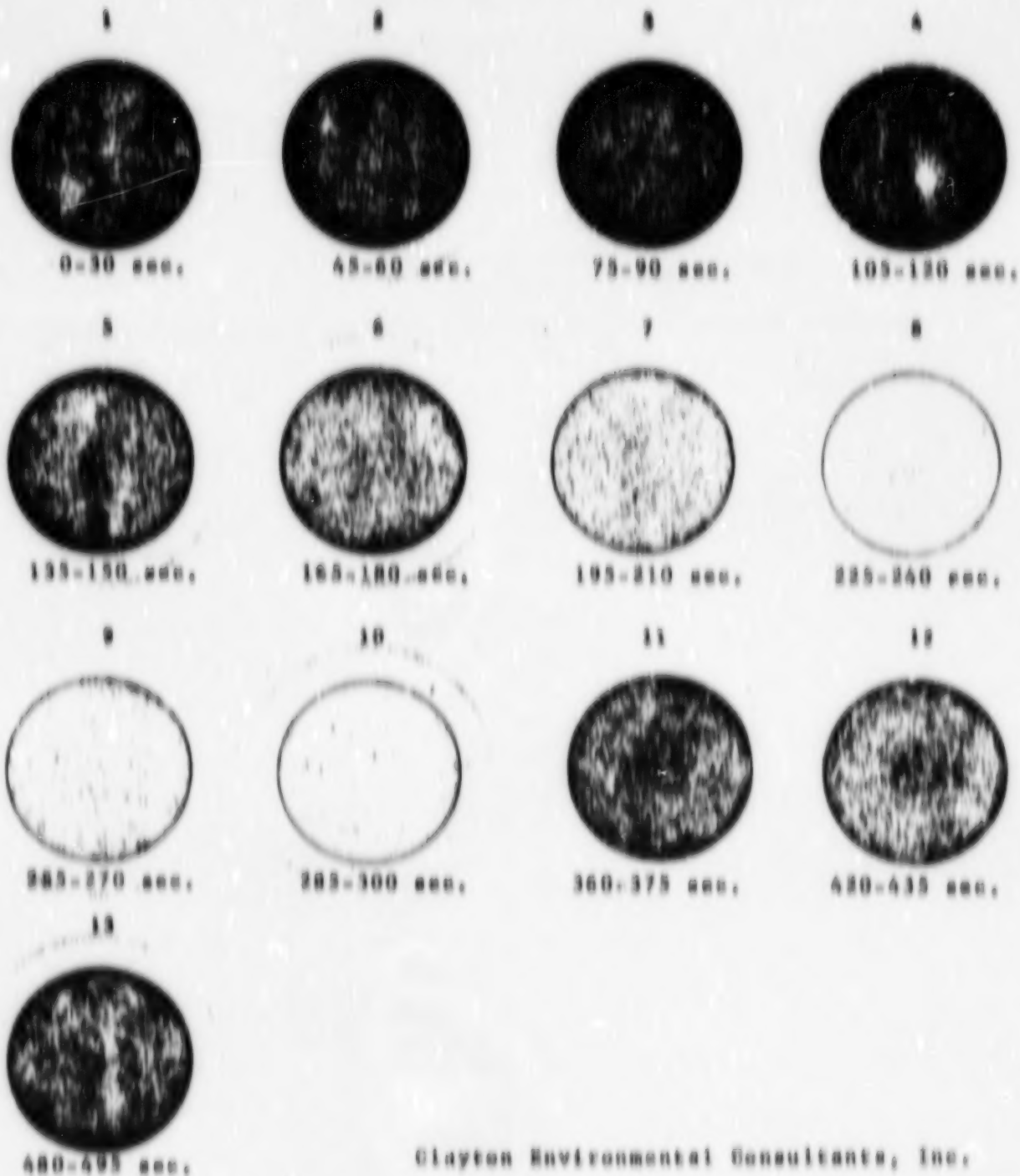


FIGURE A.4-2

SEQUENTIAL FILTER OBSCURITY TEST ON MARCH 3, 1975

Buena Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975



Clayton Environmental Consultants, Inc.

TABLE 4.4
DETERMINATION OF PEAK PARTICULATE EMISSION
PERIOD FROM THE EXHAUST DUCT

Burns Harbor Plant
Bethlehem Steel Corporation
Chester, Indiana
March 3-7, 1975

Test Number	Filter Number	Start Time (sec)	Stack Temp. (°F)	Average Plume Opacity (%)
1 (2-24-75 at 1345)	1	0	*	15
	2	30	*	50
	3	60	*	50
	4	90	*	50
	5	120	*	50
	6	150	*	40
	7	180	*	25
	8	210	*	20
	9	240	*	20
	10	270	*	20
	11	300	*	15
	12	330	*	15
	13	360	*	15
2 (3-3-75 at 1158)	100	0	75	20
	2	45	120	80
	3	75	145	60
	4	105	125	40
	5	135	105	25
	6	165	100	20
	7	195	95	20
	8	225	85	20
	9	255	80	20
	10	285	78	20
	11	360	78	20
	12	420	78	20
	13	480	78	20

* No data acquired
xx 30-second duration filter obscuration sample

4.5 Peak Particulate Emissions from Shed Exhaust Duct

"Peak" particulate sampling was performed to determine the individual contribution of pushing operation emissions to the average, continuous particulate emission rate from the uncontrolled coke-side shed. Peak particulate samples were acquired using EPA Method 3 (Final In-House Draft, 7-21-74) and variations of EPA Methods 1 and 3 (Final In-House Draft, 7-18-74 and 7-25-74, respectively). These methods are included in Appendices 7-8 (Volume 5).

The major modification to EPA Method 3 was that the peak particulate emissions were measured only during the evacuation of the shed during and immediately after coke pushing, i.e., for three minutes out of approximately 13 minutes. Thus, each peak particulate sample consisted of intermittently sampling 20 individual coke-oven pushes with the probe stationary during each push. It should be noted that, in general, the peak and continuous samples were acquired concurrently.

Because the peak particulate emission tests were conducted on an interruptible basis (i.e., sampling for three minutes and then stopping for about 10 minutes, then sampling again), the filter temperature was maintained just above the dewpoint of the stack gases.

The peak particulate samples were analysed for the materials indicated in Table 1.0-1. All sampling and analytical methods are presented in Appendix 8 (Volume 5).

4.6 Particle Size Distribution

Particle size tests were performed to define the distribution of particles entering a potential control device. Since

previous coke pushing studies have used the cascade impaction method, the sizing determinations were performed using an outside-the-stack Brink cascade impactor. Each of the four particle size samples were taken at a different single point, each representing an equal area, (at an isokinetic rate) because accurate calculation of the aerodynamic diameter of each impaction stage is impossible if the sampling rate varies during sampling (such as would result from maintaining an isokinetic rate while traversing a number of points). In addition, the particulate concentration for each of the four particle size samples was calculated for comparison to the filterable particulate concentrations resulting from 2-minute peak particulate samples. The sampling and analytical methods for particle sizing are presented in Appendix U (Volume 3).

4.7 Emissions of Other Materials

A large number of additional emission measurements were made during the course of the study. A complete roster of the emissions measured is presented in Table 1.0-1, and the purpose for obtaining each of these measurements is specified in Table 1.0-2.

Sulfur dioxide and sulfuric acid mist (sulfur trioxide) samples were acquired and analysed according to U.S. EPA Reference Method 8. Hydrogen sulfide samples were acquired and analysed according to U.S. EPA Reference Method 11. These methods are included in Appendices V and W (Volume 3), respectively.

Sampling and analytical methods for all other contaminants measured during the study are not covered by EPA-standardised

procedures. Other standard methods, such as ASTM methods, were used as much as possible. All sampling procedures were reviewed and accepted by Mr. Louis Paley, P.E., DOSH, U.S. EPA, prior to their use. Similarly, all analytical procedures were reviewed and accepted by Mr. Mark Antell, DOSH, U.S. EPA, prior to their use. A complete description of each of these sampling and analytical methods is given in Appendices E-BB (Volume 3).

4.8 Dustfall Measurements

In order to assess the impact of the coke-side shed upon particulate deposition, dustfall measurements were made using the general principles outlined in ASTM Method D-1739-70. Measurements were taken within and near the coke-side shed and at similar locations on the unshedded (No. 2) coke battery, as shown in Figure 3.1-1. Dustfall sample buckets were located at approximately equivalent positions on both benches about 13 feet above grade. Near the shed wall (on the far side of the quench car tracks), the dustfall buckets were elevated about 10 feet above grade on the far side of the railroad tracks. Each dustfall bucket was carefully positioned to avoid, as much as possible, incineration from falling coke, deformation, or other means of destruction. In addition, eight pairs of dustfall samples were acquired about three feet above grade to assess the precision of the technique.

A dustfall measurement made in the ambient air usually requires a period of 30 days. Because dustfall levels are orders of magnitude higher in the immediate vicinity of a coke battery than in ambient air, it was only necessary to expose

the dustfall buckets for periods of hours in these tests.

It should be noted that the settled dust in each can was filtered during the laboratory analysis through a No. 10 mesh screen (1-mm square) to remove large chunks of fallen coke. In addition, selected dustfall samples were analyzed for pH, acetone-soluble content, and cyclohexane-soluble content. The sampling and analytical techniques are summarized in Appendix 66 (Volume 5).

4.9 Subjective and Visual Emission Parameters

4.9.1 Degree of Greenness

The semi-quantitative measurement scale used to estimate visually the relative quantity of particulate matter released during a coke-oven push is termed "degree of greenness." In applying this technique, the duration of the coke-pushing operation was estimated and divided into thirds. The amount of visible particulate generated during each third was estimated by mentally integrating the quantity of particulate generated and recording the value on a scale of one to four ("very little" emissions to "copious" amounts of emissions, respectively). Each observation represented the total obscuration caused by the emissions from both the falling coke and the coke in the quench car. The resulting numbers for each third of each coke-oven push were then summed to give a semi-quantitative measure of emissions generated from each coke-oven push on a scale of three to 12. In addition, the same observer recorded the actual duration of the coke-pushing operation with a

stopwatch. A second estimate of the amount of emissions released, the product of the sum of the ratings and the duration of the push, was also determined. The detailed method for determination of the degree of greenness of a coke-oven push is given in Appendix DD (Volume 3).

4.9.2 Opacity of Shed Exhaust

Although Figure 3.1-2 shows the shed exhaust duct with one exit stack, in fact, two stacks were used to discharge the emissions from the shed exhaust duct during the study. Further, a third exhaust stack existed but was sealed completely during this study. Opacity data were acquired by U.S. EPA personnel for the two functional stacks using EPA Method 9. These values were averaged and thereafter treated mathematically as if there were only a single stack. A copy of the method is contained in Appendix EE (Volume 3).

4.9.3 Percent of Doors Leaking

Since door emissions appeared to be predominantly independent of either coke-pushing or quench car particulate emissions, an observation technique that recorded the quantity of oven doors leaking visibly during a short-term observation period was developed on-site. These observations yielded an estimate of the percent of coke-side doors leaking. Similar observations were made and results were calculated for the push side of the coke battery to document general process conditions. A detailed description of the basic method is provided in Appendix FF (Volume 3).

4.9.4 Visual Estimates of Fugitive Emissions

The sampling program developed to evaluate the shed leakage rate (fugitive particulate emissions) included on-site evaluation of opacity and the subsequent use of photographs of these emissions. Opacity observations were made by EPA personnel under several different process, wind, and shed leak-rate conditions using EPA Method 9 (see Appendix EE, Volume 3). Twenty-seven observations of the shed end leakage were made during randomly-selected, complete pushing cycles on four days. The observations were made while looking diagonally through the plume, as close as possible to the point of emission (shed end).

Both 16-mm black-and-white and color movies, and 35-mm color stills were taken randomly during the fugitive particulate sampling periods and during other instances of end and topside shed leakage. These photographs were used primarily to estimate the cross-sectional area (i.e., height and width) of the fugitive plume emanating from the ends and side of the shed.

4.10 Fugitive Particulate Emissions from the Shed

In addition to the opacity data and photographs discussed in Section 4.9.4, the sampling program for fugitive emissions included the measurement of fugitive particulate concentrations at three points of leakage from the shed. Each sample was taken during (visually determined) "peak" emission periods. These samples were collected using a 47-mm diameter glass-fiber filter, a calibrated limiting orifice, and a leakless diaphragm pump.

A vane-axial anemometer and a stopwatch were used to estimate the exhaust gas velocity. The sampling rate for each sample was held constant using the critical orifice in the sampling train. The critical orifice was sized initially to the average anticipated velocity based upon preliminary vane-axial anemometer measurements made in the various areas of fugitive particulate emissions. Due to spatial and temporal variations in velocity, however, these samples were acquired anisokinetically. A detailed description of the sampling and analytical methods is presented in Appendix GG (Volume 3).

These short-term (approximately 1-1/4 minutes) fugitive particulate measurements were then extrapolated to a continuous, fugitive particulate emission rate estimate. This was accomplished by using the shed leak opacity data (converted to "attenuation coefficients"⁽³⁾) as the basis for extrapolation from the short-term basis to a continuous basis. This was possible because it has been shown that mass emissions can be correlated with the attenuation coefficient for coal dust.⁽³⁾ A full description of the technique is provided in Appendix HH (Volume 3).

4.11 Calibration, Quality Assurance, and Sampling Integrity

Chain-of-custody procedures utilized during this study were followed conscientiously. Each sample was uniquely identified, and at all times either one member of the Clayton test team was with the samples or the samples were locked securely in storage.

Calibrations of all instruments were performed both prior to and after the sampling period. The critical orifices used in the fugitive particulate sampling were calibrated, even though no promulgated air pollution regulations in the United

States required calibration of these devices at the time of the study. Finally, the sample handling and analysis techniques were approved by Mr. Mark Antell (DSSR, U.S. EPA) after consultation with Clayton personnel.

The methods used for instrument calibration in this study are presented in Appendix II (Volume 5). The calibration data are given in Appendix JJ (Volume 5). A list of the samples voided during the conduct of the study and the reasons for voiding them are listed in Appendix KK (Volume 5). Field sampling data sheets are provided in Appendix LL (Volume 5), while analytical data are presented in Appendix MM (Volume 5). "Chain of Custody" procedures are given in Appendix NN (Volume 6), and example calculations are shown in Appendix OO (Volume 6). Copies of all correspondence with Bethlehem Steel Corporation are included in Appendix PP (Volume 6). Results of previous sampling by Bethlehem Steel Corporation at the Burns Harbor plant are presented in Appendix QQ (Volume 6).

5.0 PRESENTATION AND DISCUSSION OF RESULTS

5.1 Coke-Side Particulate Emissions

Two types of particulate samples were collected in the exhaust duct from the coke-side shed at the Burns Harbor plant. The first, termed "continuous" particulate emissions, spanned the entire period when pushing occurred, as well as the intervals between pushes. Sampling continued during these intervals unless process upsets or downtime exceeded 30 minutes.

The second type of sampling estimated "peak" particulate emissions from the shed. These samples were acquired by sampling intermittently during the periods found to have maximum visible emissions, i.e., the 3-minute interval which immediately followed the beginning of a push. Since both continuous and peak emissions included essentially the same pushes, the two types of samples were, in a sense, simultaneous.

It should be noted that both types of samples necessarily included quench car emissions while it was under the shed and door leaks, occurring constantly, as well as residual emissions from "old pushes." Neither type, however, included the emissions that were fugitive from the shed. It was therefore necessary to estimate these fugitive emissions by another technique.

5.1.1 Continuous Particulate Emissions from the Exhaust Duct

The continuous particulate emissions from the shed exhaust duct are summarized in Table 5.1.1. These values represent emissions from pushing, door leaks, quench car

TABLE 5.1.1

SUMMARY OF COMBUSTION PARTICULATE EMISSIONS FROM THE BURNER NO. 1 EXHAUST DUCT

Burner No. 1
 Test No. 1
 Date: 11/11/75
 Time: 10:00 AM
 Location: 11/11/75

Test No.	Stack Gas Conditions	Particulate Concentration (gr/1000 ft ³)		Particulate Emissions Rate (lb/hr)		Particulate Emissions Factor*	
		Filterable	Total	Filterable	Total	lb/tun dry coal	lb/tun coke
1	84	0.056	0.078	1.29	1.78	0.79	1.0
2	94	0.054	0.055	1.27	1.56	0.81	1.0
3	98	0.053	0.056	1.27	1.56	0.81	1.0
Average	92	0.054	0.056	1.26	1.61	0.80	1.0

* These values do not include fugitive particulate emissions (see Table 5.1.3 for overall emissions).

* Northham Steel Corporation has indicated that 0.73 ton of coke is produced per ton of wet coal charged.

movement, and the residual emissions from previous pushes, but inherently do not include fugitive emissions from the shed. The emission factors for both filterable and total particulate are relatively consistent among themselves and average 0.78 and 0.80 pound of particulate per ton of dry coal fed, or 0.99 and 1.0 pound of particulate per ton of coke produced, respectively. A more complete summary of sampling times, sampled volumes, concentrations, and emission rates can be found in Appendix RR (Volume 6).

5.1.3 Fugitive Particulate Emissions

Just prior to commencement of the study, fugitive particulate emissions were observed to be leaking from the shed at the four positions shown in Figure 3.1-2: 1) the north end of the shed, 2) the south end of the shed, 3) the Ashania valves, and 4) the boundary between the shed and the coke battery. The Ashania valves and shed-battery boundary leakage were observed to be essentially constant, while the ends leakage went through an increasing-decreasing opacity cycle similar to that of the exhaust duct emissions. Because the primary goal of this project was to measure the emissions from the coke side of the battery and not just from the shed exhaust duct, the fugitive particulate emissions escaping the shed were estimated. To accomplish this, a measurement technique was developed in the field that included short-term anisokinetic, fugitive particulate emission measurements.

Table 5.1.2 summarizes the results of these measurements. The fugitive particulate concentrations ranged from 0.002 to 0.124 grain per dry standard cubic foot (gr/DSCF). These concentrations were extrapolated to estimate the continuous fugitive particulate emission rate⁽³⁾ by the methodology presented in Appendix HH (Volume 5). The resulting estimate was 21.9 pounds of fugitive particulate per hour. Based upon an average feed rate during continuous particulate sampling of 161 tons of dry coal per hour (see Table 5.1.1), this emission rate corresponds to an emission factor of 0.16 pound of filterable particulate per ton of dry coal fed to the ovens, or 0.17 pound of filterable particulate per ton of coke produced.

Since these values estimate the fugitive filterable particulate emissions on a continuous basis, they may be related to the continuous filterable particulate emissions from the exhaust duct, which averaged 0.78 pound per ton of dry coal fed (see Section 5.1.1). The percentage of the emissions that were fugitive can then be calculated as follows:

$$\frac{0.16}{0.16 + 0.78} \times 100 = 15\%$$

Thus, approximately 15 percent of the filterable particulate emissions escaped from the shed on a continuous basis.

5.1.3 Overall Continuous Coke-Side Particulate Emissions

Using the particulate emissions data presented in the previous two sections, it is possible to estimate the

TABLE 5.1.2

MEASURED FUGITIVE PARTICULATE
EMISSIONS ESCAPING FROM THE JRED

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

1975 Date	Sample Description	Fugitive Particulate Concentration (gr/DSCF)	Velocity (ft/min)
3-5	Topside at crossover butterfly for ovens 112 & 113; Pushing oven 114	0.105	—
3-5	Topside at oven 112; Charging oven 114	0.002	—
3-5	Topside at oven 134; Charging oven 124	0.029	160
3-5	Topside; Off main at oven 134	0.077	151
3-6	North end; Pushing oven 103	0.124	276
3-6	North end; Pushing oven 123	0.006	230
3-6	North end; Pushing oven 124	0.117	—
3-6	North end; Pushing oven 125	0.027	201
3-6	North end; Pushing oven 126	0.033	353
3-6	North end; Pushing oven 123	0.024	221
3-6	South end; Pushing oven 113	0.017	337
3-6	South end; Pushing oven 121	0.051	409
3-6	South end; Pushing oven 124	0.002	171
3-6	South end; Pushing oven 121	<0.006	312

overall particulate emissions emanating from the coke side of the shed on a continuous basis. Table 5.1.3 presents both the continuous filterable particulate emissions, which do not include fugitive emissions, and the overall filterable particulate emissions. These overall emissions include emissions from pushing, door leaks, quench car movement under the shed, the residual from previous pushes, and fugitive emissions from the shed, but do not include emissions from the quench car during transit outside the shed.

The overall emission rates presented in Table 5.1.3 have been estimated by adding the average continuous fugitive emission rate developed in Section 5.1.2 to the continuous emission rate for each particulate sample. Emission factors for estimated fugitive emissions were determined by dividing this average emission rate by the coal feed rates for the individual samples presented previously in Table 5.1.1. The overall emission factors were then estimated to range from 0.89 to 0.93, and average 0.91 pound of filterable particulate per ton of dry coal fed, or 1.2 pound of filterable particulate per ton of coke produced.

5.1.4 Peak Particulate Emissions from the Shed

Table 5.1.4 presents the peak particulate emissions measured in the shed exhaust duct. These peak emissions were quantified by sampling during only the period of greatest visible emissions, i.e., the first three minutes of the approximately 13-minute interval when pushing

TABLE 5.1.3

SUMMARY OF OVERALL CONTINUOUS PARTICULATE EMISSIONS FROM THE STEEL

Barnes Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Continuous Particulate Test No.	Continuous Filterable Particulate Emissions			Estimated Fugitive Particulate Emissions			Overall Continuous Filterable Particulate Emissions Estimate		
	Emission Rate (lbs/hr)	Emission Factor		Emission Rate (lbs/hr)	Emission Factor		Emission Rate (lbs/hr)	Emission Factor	
		lbs/ton dry coal	lbs/ton dry coke		lbs/ton dry coal	lbs/ton dry coke		lbs/ton dry coal	lbs/ton dry coke
1	129	0.76	0.97	21.9	0.13	0.17	151	0.89	1.1
2	123	0.79	1.0	21.9	0.14	0.18	145	0.93	1.2
3	121	0.78	0.99	21.9	0.14	0.17	143	0.92	1.2
Average	124	0.78	0.99	21.9	0.14	0.17	146	0.91	1.2

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TABLE 3.3.4

SUMMARY OF FINE PARTICULATE EMISSIONS FROM THE BATTERY NO. 1 EXHAUST DUCT

Bureau Surface Plant
Bethlehem Steel Corporation
Chatterton, Indiana
March 3-7, 1975

Test No.	Stack Gas Conditions	Particulate Concentration (gr./1000 ft. ³)		Particulate Emission Rate* (lbs./hr.)†		Process Weight Rates*		Particulate Emission Factors*		
		Filterable	Total	Filterable	Total	tons wet coal/hr	tons dry coal/hr	lbs./ton dry coal	lbs./ton coke*	Total
1	1113 257,000	0.148	0.161	73.4	80.5	158	147	0.50	0.64	0.55
2	1208 267,000	0.121	0.230	112	136	157	146	0.77	0.98	0.79
3	1311 251,000	0.145	0.219	96.2	106	157	146	0.65	0.82	0.73
Average	1204 257,000	0.138	0.204	93.2	101	157	146	0.64	0.81	0.69
										0.87

* These values do not include fugitive particulate emissions.

† Emission rates and process weight rates assume typical operations; i.e., 4.5 pounds/hour.

* Bethlehem Steel Corporation has indicated that 0.73 ton of coke is produced per ton of wet coal charged.

emissions were being evacuated from the shed. This 3-minute sampling period was determined empirically by the methodology discussed in Section 4.6. It should be noted that because of the sampling technique, the emission rates and feed rates presented in Table 5.1.4 have been adjusted to assume typical operations; i.e., 4.5 pushes per hour. The resulting emission factors for filterable and total particulate average 0.64 and 0.69 pound of particulate per ton of dry coal fed, or 0.81 and 0.87 pound of particulate per ton of coke produced, respectively.

In addition to pushing emissions, emissions from door leaks, quench car movement, and residual concentrations from previous pushes were also observed to be exhausted during the 3-minute "peak" periods. Thus, the peak particulate emissions data presented in Table 5.1.4 should not be considered an estimate of the particulate emissions from coke pushing, per se. These additional, variable sources of particulate emissions (doors and quench car) likely account for the wider range of data reported for the peak particulate emissions from the exhaust duct as compared to the results of continuous sampling. A more complete summary of sampling times, sampled volumes, concentrations, and emission rates can be found in Appendix 55 (Volume 6).

5.1.5 Particulate Emissions for Pushing Operations

Using the particulate emissions data presented previously, together with a straightforward calculational

procedure, it is possible to estimate the particulate emissions due to pushing operations alone at Battery No. 1. By assuming that the aggregate door leak emission rate within the shed is essentially equivalent during pushing periods and non-pushing periods, the emission rate due to door leaks can be estimated algebraically by consideration of emission rate measurements from the two particulate sampling modes.

Referring to Figure 3.1.3, the total shaded area B_1 (diagonal lines upward and to the right) includes a single push and the time following that push and preceding the next push, and represents the mass of emissions occurring during the continuous particulate sampling period t_{c1} , consisting of door leaks, residuals of old pushes, and push emissions occurring during t_{c1} . Area A_1 (diagonal lines upward and to the left) represents the mass of push emissions, residual emissions, and door leaks measured during the peak particulate sampling period, t_{p1} . The time period t_{p1} represents the time required to evacuate the shed of most of the "current push emissions." The difference of the two areas, $B_1 - A_1$, is the rectangular area that represents the mass of emissions due only to door leaks and residual concentrations from previous pushes. A time-weighted fraction of this rectangle, $(B_1 - A_1) * t_{p1} / (t_{c1} - t_{p1})$, represents the "baseline" rectangular area's contribution to the total peak emissions, A_1 . Subtraction then gives an estimate of the mass emissions ascribed only to pushing:

$$\text{Push-Only Mass Emissions} = A_1 - (B_1 - A_1) \left[\frac{t_{p1}}{t_{c1} - t_{p1}} \right]$$

Test Type	Duration	Emissions Collected	Symbol
Peak	Sampling Time = $t_{p1} = t_{p1+1}$	$A_1 \neq A_{1+1}$	
Continuous	Sampling Time = $\sum t_{c1}$	$\sum A_1$	



FIGURE 5.1.5
SCHEMATIC DIAGRAM OF SAMPLING SCHEDULE

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

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The calculational procedure described above is shown in Table 5.1.5. Since all samples were taken on a multi-push basis, measured emissions were normalized to a "per-push" basis by dividing by the number of pushes included in each sample. Then, using the sampling time per push and the equation above, the pushing operations emissions captured by the shed were estimated.

Fugitive emissions which escaped capture by the shed were estimated, as discussed in Section 5.1.2, to be 13 percent (on a continuous basis) of the emissions captured by the shed. Thus, in order to determine total push emissions, the emissions captured by the shed must be adjusted upward by direct ratio using this factor. Using the process weight rates, the overall filterable particulate emission factors for the pushing operations can also be calculated. These values were found to range from 0.48 to 0.89, and average 0.69 pound per ton of dry coal fed to theovens, or 0.87 pound per ton of coke produced.

5.1.6 Particulate Emissions for Non-Pushing Operations

Using the evaluations presented in Sections 5.1.3 and 5.1.5, the emissions from non-pushing operations are calculated by difference, as shown in Table 5.1.6. These emission factors include door leaks, residuals from past pushes, and emissions from quench car movement. They have been corrected for fugitive emissions and thus provide an estimate of the overall coke-side emissions for non-pushing operations. The values range from 0.04 to 0.41, and average 0.22 pound of filterable particulate per ton of dry coal, or 0.3 pound per

TABLE 5.1.5

CALCULATION OF FILTERABLE PARTICULATE EMISSION
FACTOR FOR PUSHING OPERATIONS

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 2-7, 1975

Type of Test	Test No.	Filterable Particulate Emission Rate (lbs/hr)	Sampling Time (minutes)	Number of Overs Pushed	Filterable Particulate Emissions (lbs/push)	Sampling Time for Push (minutes)
Continuous	1	129	288	25	24.8	11.5
	2	123	288	23	25.7	12.5
	3	121	288	23	25.3	12.5
Peak	1	73.4*	60	(4.5)	16.3	3
	2	112 *	60	(4.5)	24.9	3
	3	96.2*	60	(4.5)	20.9	3

Peak Particulate Test No.	Peak Emissions Captured by the Shed (lbs/push)	Total Peak Emissions (lbs/hr)*	Process Weight Rate*		Filterable Particulate Emission Factor for Pushing Operations	
			tons wet coal/hr	tons dry coal/hr	lbs/ton dry coal	lbs/ton coke†
1	13.3	78.2	138	147	0.48	0.61
2	24.6	130	157	146	0.89	1.1
3	19.5	103	157	146	0.71	0.90
Average	19.1	101	157	146	0.69	0.87

* These emission rates and process weight rates assume typical operations; i.e., 4.5 pushes/hour.

† Bethlehem Steel Corporation has indicated that 0.73 ton of coke is produced per ton of wet coal charged.

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TABLE 5.1.6

CALCULATION OF FILTERABLE PARTICULATE EMISSION FACTOR
FOR NON-PUSHING OPERATIONS

Barns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Continuous Particulate Test No.	Overall Continuous Filterable Particulate Emission Factor		Filterable Particulate Emission Factor for Pushing Operations		Filterable Particulate Emission Factor for Non-Pushing Operations	
	lbs./ton dry coal	lbs./ton coke	lbs./ton dry coal	lbs./ton coke	lbs./ton dry coal	lbs./ton coke
1	0.89	1.1	0.48	0.61	0.41	0.5
2	0.93	1.1	0.69	1.1	0.04	0.1
3	0.92	1.2	0.71	0.90	0.21	0.3
Average	0.92	1.2	0.69	0.87	0.22	0.3

ton of coke produced. This table thus indicates that the pushing operations account for 76 percent of the overall emissions, while the non-pushing operations account for 24 percent.

5.2 Particulate Capture Efficiency of the Shed

5.2.1 Evaluation of Shed Capture Efficiency

The average emission factor for continuous filterable particulate emissions from the exhaust duct was 0.78 pound per ton of dry coal fed to the oven, as shown in Table 5.1.1. Using the average fugitive emission factor developed in Section 5.1.2, 0.14 pound per ton of dry coal, the particulate capture efficiency of the shed may be calculated as follows:

$$\left[1 - 0.14 / (0.14 + 0.78) \right] \times 100 = 85\%.$$

Thus, on a continuous basis, an average of 85 percent of the filterable particulate emissions are captured by the shed.

5.2.2 Possible Causes of Leakage

The following are possible reasons for the shed's fugitive particulate emissions:

1. The overall size of the shed's holding chamber (see Figures 3.1-2 and 3.1-3) appeared to be too small relative to the magnitude of the emissions and the effective evacuation rate of the shed. This was substantiated by the exhaust duct opacity observations, which documented that the shed was not completely cleared of push

emissions in 2 to 3 minutes (as designed, per Mr. Robert Harvey of Bethlehem Steel Corporation). Instead it appeared that clearing of the push (push) emissions sometimes took longer than 10 minutes (perhaps 14 to 15 minutes). This is important for two reasons:

- a. The shed's holding and evacuation capacities may have been exceeded in the many (32 percent) instances when the time between pushes was only 8 to 9 minutes; i.e., below the "average" cycle duration of 13 minutes. This meant an 8- to 9-minute push-to-push interval was slightly below the "observed" period required for push emissions clearing. Shed leakage was likely also increased by the (not infrequent) occurrence of highly emissive ("green") coke-oven pushes. When the shed's capacities were exceeded, the particulate emissions "overflowed" from any openings below the shed's holding chamber. In this event, some of the particulate material suspended in the shed's holding chamber likely moved beyond the "capture" range of the exhaust duct and into the region where wind effects were more pronounced. The probable result of this "undersizing" was leakage from any shed openings such as those located at both ends of the shed and topside.

b. The hot, particulate-laden gases may have also dropped beyond the reach of the exhaust duct because of cooling caused by the attempt to hold the emissions in the holding chamber beyond the design duration.

2. As implied in the first item, perhaps the shed exhaust rate was too low. During the test period, exhaust gas flowrate measurements indicated that airflow was about 10 percent below the rate identified by the facility to be its optimum rate on the basis of emission clearing time. However, assurances were given by Bethlehem Steel Corporation that the exhaust rate was at maximum conditions and, since the stack gas exhaust rate was within the ± 10 percent criterion discussed in Section 3.2.1, sampling commenced.

3. It is possible that "short circuiting" of the outside air (which enters the shed through its ends and open side) to the exhaust duct occurred due to the: (1) magnitude of the openings, particularly at the ends of the shed; and (2) the varying cross-sectional area of the openings. If this happened, the "actual" emission exhaust rate would be reduced. This phenomenon could have further reduced the shed's performance because the resulting inlet airflow pattern would disturb, rather than enhance, the desired pattern of airflow in the shed.

4. The capture problem may have been caused, at least in part, by the holding chamber, its inlet, and/or the exhaust duct:
 - a. The shape of the shed's holding chamber, in conjunction with the size of its inlet ("throat") might have affected the shed's initial emission capture efficiency and subsequent holding capacity.
 - b. The shape, size, and location of the exhaust duct (located at the top of the holding chamber) may have significantly affected the rate and efficiency of its emission exhaust.
5. The shed wall and end openings may have further affected the performance in three ways:
 - a. Such openings provided potential escape routes for fugitive emissions.
 - b. At least some of the openings appeared to allow the wind to interact with the emissions within the shed. Several instances were observed when the wind blew coke-side door leaks directly out the end of the shed, before they were captured.
 - c. The relatively large end openings may not have permitted optimum use of the inlet air. Ideally, the air should have entered the shed uniformly, and preferably only along its open side. This would have enhanced the

entrainment of the particulate emissions by reinforcing the spiral air pattern being established in the shed by the combined effect of the rising hot emission gases and the shape of the shed holding chamber.

5.3 Chemical Composition of Particulate Emissions

Nineteen separate analyses of the particulate samples (both continuous and peak) were performed. Table 5.3-1 presents the results of the analyses for sulfate and 10 metal ions in terms of percent of both filterable and total particulate weight. The contribution of these substances to the particulate emissions was quite small. The only substance found in an amount greater than one percent was sulfate (2.3 to 4.5 percent). Thus, carbonaceous material (coke) constituted the majority of the particulate matter captured.

Table 5.3-2 presents the average emission rates for these 11 substances as well as the average emissions of acetone-soluble particulate, water-soluble particulate, and other water-soluble substances. Note that in this table emission rates for peak samples have been adjusted to an average pushing rate of 4.5 pushes per hour. The acetone-soluble content of the filterable continuous and peak emissions averaged 13 and 12 percent, respectively. The water-soluble content averaged two percent for both types of samples.

Table 5.3-3 presents the pH and acidity of the front and back-half catches of each of the particulate samples. Although the values vary, all fractions were found to be acidic.

5.4 Particle Size Distribution

The results of the four particle size samples are plotted in Figure 5.4. The lines are labeled according to the point within

TABLE 5.3-1

SUMMARY OF METALS AND SULFATE CONTENT OF PARTICULATE SAMPLES (PERCENT)

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Sampling Conditions	Test No.	Portion of Sampling Train	Percent of Particulate Weight									
			Ca	Fe	Mg	Pb	Al	Cd	Cu	Se	Si	SO ₄
Continuous	1	Front	0.01	0.9	0.01	0.01	0.6	0.0004	0.02	<0.0006	0.002	0.1
		Total	0.02	0.9	0.01	0.01	0.6	0.0004	0.02	<0.0005	0.002	0.05
	2	Front	0.03	0.9	0.007	0.004	0.2	0.0002	0.002	<0.0006	<0.0008	0.04
		Total	0.04	0.9	0.008	0.004	0.2	0.0002	0.002	<0.0007	<0.002	0.04
	3	Front	0.02	0.5	0.01	0.006	0.6	0.0002	0.042	<0.0006	<0.002	0.04
		Total	0.03	0.5	0.01	0.006	0.5	0.0004	0.002	<0.0007	<0.002	0.03
Peak	1	Front	0.03	0.8	0.02	0.005	0.4	0.0008	0.0006	<0.001	<0.003	0.04
		Total	0.06	0.7	0.02	0.005	0.4	0.0007	0.0005	<0.001	<0.004	0.04
	2	Front	0.01	0.8	0.01	0.003	0.2	0.0008	0.003	<0.0007	<0.002	0.06
		Total	0.02	0.8	0.01	0.003	0.1	0.0009	0.003	<0.0008	<0.003	0.06
	3	Front	0.005	0.8	0.001	0.004	0.3	0.0003	<0.0003	<0.0008	<0.002	0.03
		Total	0.02	0.7	0.003	0.004	0.3	0.0004	0.001	<0.0008	0.004	0.04

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TABLE 5.3-2

SUMMARY OF AVERAGE RATES OF PARTICULATE EMISSIONS FROM EXHAUST DUCT

Jones Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Material	Average Emission Rate			
	Continuous Emissions		Peak Emissions*	
	lbs/hr	kg/hr	lbs/hr	kg/hr
Filtrable Particulate	124	56.3	93.2	42.2
Total Particulate	129	58.5	101	45.8
Formic-Soluble Acetone Solubles	16.6	7.5	10.8	4.9
Total Acetone Solubles	18.5	8.4	17.6	8.0
Formic-Soluble Water Solubles	1.9	0.91	1.4	0.62
Total Water Solubles	5.2	2.4	3.7	1.7
Formic-Soluble Insoluble Arsenic	<0.004	<0.002	0.001-0.002	0.0004-0.0009
Total Water-Soluble Arsenic	0.003-0.006	0.001-0.003	0.001-0.003	0.0004-0.001
Formic-Soluble Water-Soluble Chloride	2.8	1.3	1.5	0.68
Total Water-Soluble Chloride	3.0	1.4	2.4	1.1
Formic-Soluble Water-Soluble Simple Cyanide	<0.003	<0.001	0.0004-0.001	0.0002-0.0008
Total Water-Soluble Simple Cyanide	<0.005	<0.002	0.0004-0.003	0.0002-0.001
Formic-Soluble Water-Soluble Mercury	<0.001	<0.0007	<0.0002	<0.0003
Total Water-Soluble Mercury	<0.002	<0.001	<0.001	<0.0006
Formic-Soluble Calcium	0.03	0.01	0.02	0.007
Total Calcium	0.04	0.02	0.03	0.01
Formic-Soluble Iron	1.0	0.5	0.7	0.3
Total Iron	1.8	0.5	0.7	0.3

* All data converted to typical operations:
i.e., 4.5 pphm/hr

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TABLE 5.3-2 (continued)

SUMMARY OF AVERAGE RATES OF PARTICULATE EMISSIONS FROM EXHAUST DUCT

Burns Jacket Plant
 Bethlehem Steel Corporation
 Chas. Vectors, Indiana
 March 3-7, 1975

Metalloid	Average Emission Rate			
	Continuous Emissions		Peak Emissions *	
	Lbs./hr.	kga/hr.	Lbs./hr.	kga/hr.
Elemental Magnesium	0.01	0.004	0.01	2.005
Elemental Magnesium	0.01	0.004	0.01	0.005
Elemental Lead	0.007	0.003	0.004	0.002
Elemental Lead	0.007	0.003	0.004	0.002
Elemental Aluminum	0.6	0.3	0.3	0.1
Elemental Aluminum	0.6	0.3	0.3	0.1
Elemental Cadmium	0.0004	0.0002	0.0004	0.0003
Elemental Cadmium	0.0005	0.0002	0.0004	0.0003
Elemental Copper	0.01	0.005	0.005-0.001	0.0004
Elemental Copper	0.01	0.005	0.001	0.0004
Elemental Beryllium	<0.0007	<0.0003	<0.0007	<0.0003
Elemental Beryllium	<0.0008	<0.0004	<0.0009	<0.0004
Elemental Selenium	0.001-0.002	0.0005-0.0009	<0.002	<0.0009
Elemental Selenium	0.001-0.003	0.0005-0.001	0.001-0.003	0.0007-0.001
Elemental Titanium	0.06	0.03	0.04	0.02
Elemental Titanium	0.06	0.03	0.04	0.02
Elemental Solid Oxide	4.1	1.9	2.4	1.1
Elemental Solid Oxide	5.7	2.6	3.1	1.4

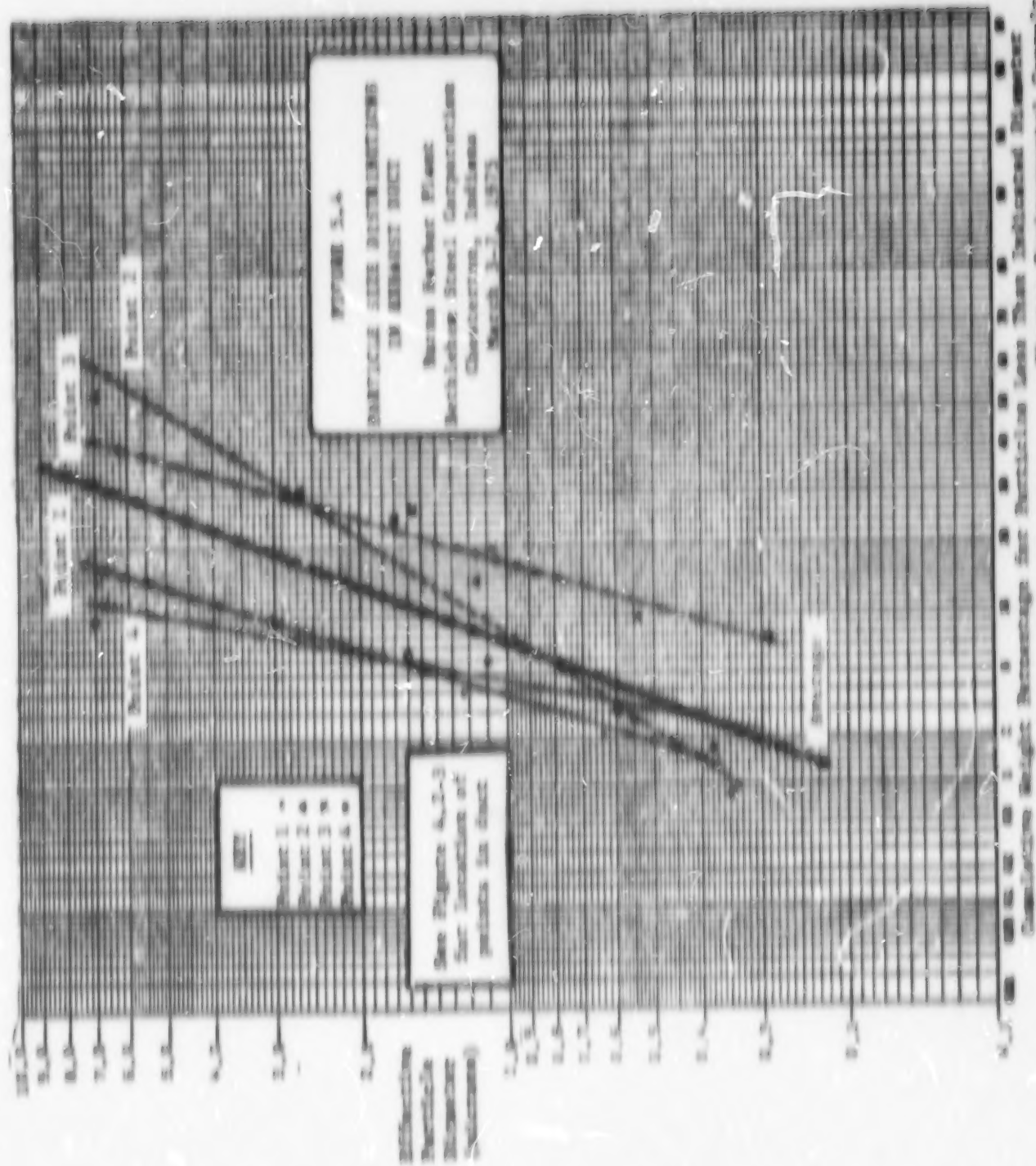
* All data converted to typical operations.

TABLE 3.2-3

SUMMARY OF WATER SOLUBLE pH
AND ACIDITY/ALKALINITY OF PARTICULATE SAMPLESBurns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Sampling Conditions	Test No.	Portion of Sampling Train	pH	Acidity*
Continuous	1	Front	3.0	2.2
	1	Back	4.9	0.9
	2	Front	6.6	≤0.3
	2	Back	4.2	0.2
	3	Front	3.1	1.3
	3	Back	3.8	0.3
Pushes Only	1	Front	5.8	≤0.3
	1	Back	4.9	0.4
	2	Front	4.4	0.2
	2	Back	4.3	0.5
	3	Front	2.9	0.6
	3	Back	4.3	0.4

* Total milliequivalents of NaOH added to attain a pH of 7.0



Concentration Weight Percentage in Exhaust Duct from Industrial Plant

the exhaust duct at which the sample was obtained, shown previously in Figure 4.2-3. The weights for each stage and the individual distributions are presented in Appendix TT (Volume 8). These data show that the particle size distribution varies somewhat across the duct, probably due to the changes in direction of the exhaust gas flow within the duct. However, a statistical comparison (chi-square test for independence) of the percentage of particulate less than one micron and the percentage less than five microns shows no statistically significant difference among the four particle size distributions.

The data in Figure 5.4 indicate that between 12 and 62 percent (by weight) of the filterable particulate was smaller than seven microns (aerodynamic diameter). Further, between four and 17 percent of the filterable particulate was smaller than one micron (aerodynamic diameter). The average stack-gas particle-size distribution can be estimated by averaging the distributions in Figure 5.4. Based on this procedure, about 32 percent of the filterable particulate was smaller than seven microns, and about seven percent was smaller than one micron.

The concentration of filterable particulate matter was also calculated for each of the particle size samples. The results, displayed in Table 5.4, indicate a range from 0.105 to 0.280 gr/DSCF. Since the sampling period for each of these tests included a single push and ranged from eight to 12 minutes, these concentrations should fall (on an average basis) between those obtained during continuous and peak particulate sampling, which they do. Thus, these results compare favorably with those obtained during the particulate tests.

TABLE 3.4
PARTICULATE CONCENTRATION AND ACETONE-SOLUBLE
CONTENT OF PARTICLE SIZE SAMPLES

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Sampling Point Number	1975 Date	Sampling Period		Particulate Concentration ($\mu\text{g}/\text{DSOF}$)	Percent Acetone Solubles
		Start	Stop		
P-1	3-6	09:05	09:13	0.260	48
P-2	5-6	18:26	18:38	0.142	63
P-3	3-7	08:27	08:33	0.105	13
P-4	3-6	12:59	13:07	0.147	34

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Table 5.4 also indicates the acetone-soluble content for each of the samples. These values vary greatly, ranging from 13 to 63 percent. In addition, the acetone-soluble content was determined for three fractions of each test: the particulate matter collected in the cyclone, that collected on the five stages of the impactor, and that collected on the back-up filter. This breakdown of the acetone-soluble content by size ranges is given in the tables included in Appendix TT (Volume 6). A statistical test (one-way analysis of variance) indicates that there is no statistically significant difference between the mean acetone-soluble content of these various size ranges.

5.5 Emissions of Other Materials

Table 5.5 presents the average emissions for all contaminants other than particulate matter. The following substances were measured at levels exceeding 100 pounds per hour: cyclohexane insolubles (203 lbs/hr), cyclohexane solubles (291 lbs/hr), ethylene and homologues (167 lbs/hr), and total light hydrocarbons (131 lbs/hr). Other contaminants were detected at levels that averaged less than 16 pounds per hour: acetylene, ammonia, benzene, benzene homologues, benzo(a+e)pyrene, β -naphthylamine, carbon monoxide, soluble chloride, chrysene plus triphenylene plus 1,2-benzanthracene, complex soluble cyanide, insoluble cyanide, simple soluble cyanide, fluoranthene, hydrogen sulfide, methane and homologues, nitrate plus nitrite, total insoluble phenolics, total soluble phenolics, pyrene, pyridine, insoluble sulfate, total sulfate, total sulfite, sulfur dioxide, and sulfuric acid mist. The sampled volumes and sampling conditions, as well as concentrations and emission rates for individual tests, are presented in Appendix UU (Volume 6).

TABLE 9.3

SUMMARY OF AVERAGE EMISSION RATES OF "OTHER" EMISSIONS

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

	Average Emission Rate	
	lbs/hr	kgs/hr
Acetylene	0.4-0.8*	0.3*
Ammonia	0.34-0.44	0.16-0.20
Benzene	4.1	1.9
Benzene Homologues (as C_6H_6)	<1.7	<0.77
Benzo(a)Pyrene	0.9-1.2	0.4-0.5
Beta-Naphthylamine	<0.35	<0.16
Carbon Monoxide	6.9*	3.2*
Soluble Chloride	4.6	2.1
Chrysene + Triphenylene + 1,2-Benzanthracene (as Chrysene)	0.8-1.3	0.4-0.6
Complex Soluble Cyanide	0.03	0.01
Insoluble Cyanide	0.01	0.004-0.005
Simple Soluble Cyanide	0.03	0.01
Cyclohexane Insolubles	203	92
Cyclohexane Solubles	291	132
Ethylene & Homologues (as C_2H_4)	147*	67*
Fluoranthene	0.7-1.2	0.3-0.6
Total Light Hydrocarbons (as CH_4)	131*	60*
Hydrogen Sulfide	0.93	0.42
Methane & Homologues (as CH_4)	5.8*	2.7*
Nitrates + Nitrite (as NO_3)	0.33-0.40	0.15-0.18
Total Insoluble Phenolics (as C_6H_5OH)	<0.06	<0.03
Total Soluble Phenolics (as C_6H_5OH)	0.89	0.40
Pyrene	<0.86	<0.39
Pyridine	<0.15	<0.07
Insoluble Sulfate	<0.13	<0.03
Total Sulfate	15.7	7.2
Total Sulfite	6.2	2.8
Sulfur Dioxide	12.6	5.7
Sulfuric Acid Mist (as SO_3)	2.2	1.0

* Emissions measured during peak periods. These data have been converted to typical operations; i.e., 4.5 pushes/hour. All other samples were taken on a continuous basis.

The sum of the average cyclohexane-soluble and cyclohexane-insoluble emissions (termed category "1") should be comparable to the sum of the average emission rates for total particulate and organic mists and gases (termed category "2"). This is to be expected because the sampling and analytical procedures tend to indicate that the materials captured, measured, and classified by the two procedures should have approximately the same aggregate value. A comparison of these two categories does indicate approximately the same emission rate; category "2" is about 86 percent of category "1." Thus, the two individual contaminant categories "cyclohexane solubles" and "cyclohexane insolubles" should be considered a single category to be compared with the sum of the total particulate and organic materials emissions, and not as separate emissions.

It should be noted that, in the field, low ambient temperatures caused freeze-up of the (standard) impinger solution containing cyclohexane; midget impingers (where temperature could be controlled) were substituted, but sampling rates were below isokinetic conditions. Because the ambient temperature precluded isokinetic sampling for cyclohexane solubles, cyclohexane insolubles, fluoranthene, pyrene, chrysene plus triphenylene plus 1,2-benzanthracene, and benzo(a)pyrene, the reported results may be somewhat high for these contaminants. In retrospect, this alteration in field sampling was favorable with respect to the measurement of fluoranthene, pyrene, chrysene plus triphenylene plus 1,2-benzanthracene, and benzo(a)pyrene because these contaminants may otherwise have been found to be below limits of analytical detection.

5.6 Indices of Visible Emissions

5.6.1 Degree of Greenness

During the design of the study, it became necessary to develop a semi-quantitative measurement scale to document the relative degree of visible particulate emissions generated by the coke ovens during pushing. The method and measurement scale formulated to characterize an observer's estimate of the emissions (visible obscuration) generated from a single coke-oven push (coke fall and quench car movement) incorporates the term "degree of greenness," a term used widely in the steel industry as a subjective assessment of the appearance of visible emissions generated from coke-oven pushing.

Specific applications of this index are demonstrated in Tables 5.6.1-1 through 5.6.1-6, which present the degree-of-greenness ratings, the sum of the ratings, and the product of the sum of the ratings and the duration of the push for each individual push during both the continuous and peak particulate samples. The average product of the sum of the ratings and the duration of the push for the six tests ranged from 222 for Peak Particulate Test No. 1 to 285 for Peak Particulate Test No. 3. Thus, the third sampling period contained pushes of higher greenness ratings than did the other two sampling periods.

Table 5.6.1-7 presents the degree-of-greenness data for the particle size samples, each of which was conducted during a single push. The three samples for which greenness data were obtained had relatively high values, ranging from

TABLE 5.6.1-1

CHARACTERISTICS OF INDIVIDUAL PUSHES DURING PARTICULATE SAMPLING
CONTINUOUS PARTICULATE TEST NO. 1

Burns Boiler Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 4, 1975

Push Time	Oven Pushed	Sec. Cooking Time (Minutes)	Degree of Greenness				Average Opacity for Two Exhaust Stacks, %		Average Flue Temperature (°F)
			Ratings	Sum	Duration (Seconds)	Sum X	Duration		
							0-3 Minutes	Remainder	
09-42	133	1044	3, 3, 3	9	25	225	—	—	2420
09-50	143	1042	3, 2, 3	8	23	184	45	15	—
10-03	153	1047	3, 2, 3	8	27	216	45	15	—
10-17	163	1051	3, 2, 2	7	28	196	45	20	—
10-27	173	1052	3, 2, 3	8	26	208	50	15	2410
10-39	183	1038	3, 3, 3	9	23	207	45	18	—
10-54	185	1046	4, 4, 4	12	23	276	55	15	—
11-04	115	1044	3, 4, 3	10	28	280	45	15	2370
11-14	135	1046	3, 2, 4	9	24	216	40	15	—
11-34	145	1046	3, 2, 3	8	23	184	40	20	—
11-46	155	1035	2, 2, 3	7	—	—	65	20	—
11-53	165	1035	3, 2, 3	8	27	216	—	—	—
12-08	117	1092	3, 3, 3	9	26	234	35	5	2370
12-48	127	1098	3, 2, 3	8	23	184	25	5	2410
13-55	137	1096	2, 2, 3	7	24	168	25	5	—
15-47	191	1146	2, 2, 3	7	24	168	—	—	—
15-56	129	1112	3, 2, 3	8	23	184	—	—	—
16-10	139	1132	3, 4, 3	10	28	280	—	—	—
16-18	149	1101	3, 2, 3	8	28	324	—	—	—
16-28	159	1101	3, 2, 3	8	28	324	—	—	—
16-36	169	1101	4, 4, 3	11	32	352	—	—	—
16-46	179	1108	3, 2, 3	8	29	224	—	—	—
16-53	189	1048	4, 3, 3	10	30	300	—	—	—
17-04	101	1048	3, 2, 3	8	26	208	—	—	—
17-13	112	1047	3, 4, 3	10	28	280	—	—	—
Average		1081	—	9	26	227	45	15	2480

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TABLE 5.6.1-1-2

CHARACTERISTICS OF INDIVIDUAL PUSHERS DURING PARTICULATE SAMPLING
 NEAR PARTICULATE TEST NO. 1

Burns Harbor Plant
 Bethlehem Steel Corporation
 Chester, Indiana
 March 4, 1975

Push Time	Over Push/4	Net Caking Time (minutes)	Degree of Greenness			Average Specific Grav. Ten Exhaust Stacks, %		Average Flue Temperature (°F)	
			Ratings	Sum	Duration (Seconds)	Sum X	9-3 Minutes		
							9-3 Minutes		Normalizer
09-42	133	1044	3, 3, 3	9	25	225	—	2420	
09-50	143	1042	3, 2, 3	8	23	184	45	—	
10-03	153	1047	3, 2, 3	8	27	216	45	—	
10-17	163	1051	3, 2, 2	7	28	196	45	2430	
10-27	173	1052	3, 2, 3	8	26	208	50	2400	
10-39	183	1038	3, 3, 3	9	23	207	45	—	
10-54	185	1044	4, 4, 4	12	23	276	55	—	
11-04	195	1044	3, 4, 3	10	20	280	45	2570	
11-14	135	1044	3, 2, 4	9	24	216	45	—	
11-31	145	1046	3, 2, 3	8	23	184	40	—	
12-28	117	1092	3, 3, 3	9	26	234	35	2370	
13-45	127	1098	3, 2, 3	8	23	164	25	2430	
13-55	137	1096	2, 2, 3	7	24	168	25	—	
15-47	191	1444	2, 2, 3	7	24	168	—	—	
15-56	129	1112	3, 2, 3	8	23	184	—	—	
16-10	139	1102	3, 4, 3	10	28	280	—	—	
16-18	149	1101	3, 2, 3	8	28	224	—	—	
16-28	159	1101	3, 2, 3	8	28	224	—	—	
16-35	169	1101	4, 4, 3	11	32	352	—	—	
16-45	179	1108	3, 2, 3	8	28	224	—	—	
Average		1090	—	9	26	222	40	2430	

TABLE 5.6.1-3

CHARACTERISTICS OF INDIVIDUAL PUSHERS DURING PARTICULATE SAMPLING
CONTINUOUS PARTICULATE TEST NO. 2

Burns Harbor Plant
Bethlehem Steel Corporation
Chester, Indiana
March 5, 1975

Push Time	Over Pushed	Net Coking Time (Minutes)	Degree of Greenness			Sum X Duration (Seconds)	Sum X Duration	Average Spacing for Two Exhaust Stacks, %		Average Flue Temperature (°F)
			Rating	Sum	Duration (Seconds)			0-3 Minutes	Remainder	
09-07	119	1035	3,3,3	9	23	207	207	—	—	2438
09-15	129	1035	4,3,3	10	25	250	250	—	—	2438
09-54	139	1040	3,2,3	8	25	200	200	—	—	—
10-38	169	1048	3,3,3	9	25	225	225	65	15	—
10-47	179	1069	3,2,3	8	28	224	224	55	10	—
10-55	189	1065	4,3,3	10	25	250	250	65	10	—
11-07	102	1069	4,4,3	11	24	264	264	—	—	2438
11-18	117	1069	3,2,2	7	25	175	175	35	10	—
11-40	122	1080	5,3,2	8	25	200	200	50	10	—
14-23	134	1045	3,3,4	10	32	320	320	40	10	—
14-43	154	1048	3,2,3	8	31	248	248	—	—	—
14-50	164	1045	3,2,3	8	31	248	248	40	10	—
15-04	174	1050	3,2,3	8	30	240	240	60	10	—
15-13	184	1048	3,2,2	7	27	189	189	30	5	—
15-22	191	1397	—	—	—	—	—	25	20	—
15-33	116	1045	3,2,3	8	30	240	240	40	10	—
15-43	126	1049	3,2,3	8	33	264	264	30	10	—
15-54	136	1050	2,3,3	8	30	240	240	30	15	—
16-02	146	1050	3,2,3	8	32	256	256	40	10	—
16-17	156	1058	2,2,3	7	26	182	182	—	—	—
16-28	166	1062	3,2,3	8	28	224	224	—	—	—
16-36	176	1063	4,3,4	11	28	308	308	—	—	—
16-44	186	1035	4,4,3	11	32	352	352	—	—	—
Average		1049	—	9	28	241	241	40	10	2438

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TABLE 5.6.1-4

CHARACTERISTICS OF INDIVIDUAL PASSES DURING PARTICULATE SAMPLING
 PEAK PARTICULATE TEST NO. 2

Burns Harbor Plant
 Bethlehem Steel Corporation
 Chester, Indiana
 March 5, 1975

Push Time	Oven Pushed	Net Coking Time (Minutes)	Degree of Greenness			Average Specific Surface Exhaust Stacks, %		Average Flue Temperature (°F)
			Rating	Sum	Duration (Seconds)	Sum X	0-3 Minutes	
10-54	119	1060	3, 4, 3	8	25	200	—	—
10-58	124	1068	3, 3, 3	9	25	225	65	—
10-47	179	1069	3, 2, 3	8	28	224	55	—
10-55	189	1065	4, 3, 3	10	25	250	65	—
11-07	182	1069	4, 4, 3	11	24	264	—	2400
11-18	112	1069	3, 2, 2	7	25	175	35	2400
11-40	122	1080	3, 3, 2	8	25	200	50	—
11-49	132	1080	2, 3, 2	7	26	182	30	—
12-00	142	1083	4, 2, 3	9	26	234	45	—
12-09	152	1081	3, 2, 3	8	25	200	—	2540
14-32	164	1045	3, 2, 2	7	32	224	45	2340
14-43	154	1048	3, 2, 3	8	31	248	—	—
14-50	164	1045	3, 2, 3	8	31	248	40	—
15-04	174	1050	3, 2, 3	8	30	240	30	—
15-13	184	1048	3, 2, 2	7	27	189	30	—
15-33	116	1045	3, 2, 3	8	30	240	40	—
15-45	126	1049	3, 2, 3	8	33	264	30	—
15-54	136	1050	2, 3, 3	8	30	240	30	—
16-02	146	1050	3, 2, 3	8	32	256	40	—
16-17	156	1058	2, 2, 3	7	26	182	—	—
Average		1061	—	8	28	224	45	2440

TABLE 5.6.1-5
CHARACTERISTICS OF INDIVIDUAL PUSHES DURING PARTICULATE SAMPLING
CORRIGENDUM PARTICULATE TEST NO. 3

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 6, 1975

Push Time	Oven Pushed	Net Caking Time (Minutes)	Degree of Greenness			Average Opacity for Two Exhaust Stacks, %		Average Flue Temperature (°F)
			Baggage	Sum	Duration (Seconds)	Sum X Duration	0-3 Minutes Remainder	
09-50	156	1036	2,3,4	9	28	252	45	-
10-05	166	1040	3,2,3	8	27	216	45	-
10-17	176	1045	4,3,4	11	30	330	90	2340
10-36	186	1052	3,3,4	10	32	320	70	2290
10-58	108	1035	4,4,4	12	30	360	70	2340
11-07	118	1036	4,3,4	11	26	286	75	2350
11-15	129	1037	3,2,3	8	26	208	65	-
12-02	168	1050	4,3,3	10	30	300	-	-
12-15	178	1035	3,3,4	10	28	280	60	2360
12-25	188	1035	4,4,4	12	32	384	70	2320
13-33	151	1046	3,2,3	8	28	224	40	2410
13-42	161	1047	2,1,3	6	28	168	35	-
13-50	171	1035	3,3,4	10	29	296	60	-
14-13	181	1035	3,3,2	8	30	240	35	-
14-28	103	1035	4,3,4	11	57	627	20	2290
14-36	113	1035	4,4,5	11	27	297	50	2360
14-47	123	1035	2,2,4	8	28	224	50	-
15-04	191	(1534)	1,1,2	4	-	-	30	-
15-13	133	1051	3,2,3	8	28	224	-	-
15-24	143	1040	3,2,3	8	25	200	-	-
15-40	153	1049	3,2,3	8	28	224	-	-
15-51	163	1038	3,2,3	8	29	232	-	-
15-59	173	1035	3,4,4	11	30	330	-	-
Average		1062	-	9	30	283	55	2358

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TABLE 5.6.1-6

CHARACTERISTICS OF INDIVIDUAL PUSHES DURING PARTICULATE SAMPLING
PEAK PARTICULATE TEST NO. 3

Burns Harbor Plant
Bethlehem Steel Corporation
Chatterton, Indiana
March 6, 1975

Push Time	Oven Pushed	No. Coking Time (minutes)	Degree of Greenness			Average Opacity for Two Exhaust Stacks, %		Average Flue Temperature (°F)
			Rating	Sum	Duration (Seconds)	Sum Duration	0-3 Minutes	Remainder
10-50	156	1038	2,3,4	9	28	252	45	20
10-17	176	1045	4,3,4	11	30	330	80	25
10-36	186	1052	3,3,4	10	32	320	70	25
10-58	108	1035	4,4,4	12	30	360	70	25
11-07	118	1036	4,3,4	11	26	286	75	25
11-15	128	1037	3,2,3	8	26	208	65	28
11-32	158	1040	3,2,4	9	30	270	—	—
11-02	168	1050	4,3,3	10	30	300	—	—
12-15	178	1035	3,3,4	10	28	280	60	30
12-25	188	1035	4,4,4	12	32	384	70	30
13-33	151	1046	3,2,3	8	28	224	45	25
13-42	161	1047	2,1,3	6	28	168	35	25
14-28	103	1035	4,3,4	11	57	627	80	25
14-36	113	1025	4,4,3	11	27	257	50	25
14-47	123	1035	2,2,4	8	28	224	50	25
15-06	191	(1534)	1,1,2	4	—	—	30	25
15-13	133	1051	3,2,3	8	28	224	—	—
15-24	143	1040	4,2,3	9	25	200	—	—
15-40	153	1049	3,2,3	8	28	224	—	—
15-51	163	1038	3,2,3	8	29	232	—	—
Average		1066	—	9	30	295	60	25
								2338

TABLE 5.6.1-7

FISH CHARACTERISTICS DURING PARTIAL SUN SAMPLING

Burns Harbor Plant
Bethlehem Steel Corporation
Chesapeake, Indiana
March 6-7, 1975

Sampling Point Number	Oven Number	Net Cooking Time (Minutes)	Degree of Greasiness			Average Quantity for Two Exhaust Stacks, 2		Average Temperature (°F)
			Readings	Size	Duration (Seconds)	Item 1 Duration	0-3 Minutes Readings	
P-1	116	1035	3,4,3	10	30	300	-	-
P-2	107	1035	4,3,3	10	20	280	-	-
P-3	171	1100	-	-	-	-	-	2400
P-4	131	1040	4,4,3	11	20	300	55	-

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280 to 300. The field data sheets for these greenness ratings, as well as those from the particulate samples, are presented in Appendix VV (Volume 6):

5.6.2 Opacity

5.6.2.1 Emissions from Exhaust Duct

Although Figure 3.1-2 schematically shows the shed exhaust duct with one exit stack, in fact, two stacks were used to discharge the emissions from the shed exhaust duct during the study. Further, a third exhaust stack was sealed completely during this study. The opacity data acquired for the two stacks were averaged and thereafter treated mathematically as if there were only a single stack. These average opacity data for the 3-minute peak periods during the particulate sampling, as well as the entire period following each push, are presented in Tables 5.6.1-1 through 5.6.1-6. The average 3-minute opacities for pushes during the sampling periods ranged from 40 for Peak Particulate Test No. 1 and Continuous Particulate Test No. 2, to 60 for Peak Particulate Test No. 3. The field data sheets from which these values were summarized are presented in Appendix WW (Volume 6):

The exhaust duct opacity data were used for the following purposes:

1. To assess the length of time required to evacuate the coke-pushing emissions from the shed (see Section 4.4):

2. To develop correlations with:
 - a. Greenness;
 - b. Hot coking time; and
 - c. Average crosswall temperature; and
3. To determine the representativeness of process conditions.

5.6.2.2 Fugitive Emissions

Observations of the coke-side shed made during the course of the study indicated that fugitive particulate emissions escaped topside, from Askenis Valve positions, and from both ends of the shed, as shown in Figure 3.1-2. The sampling program developed to evaluate this shed leakage (fugitive particulate emissions) included both the evaluation of the opacity of these fugitive emissions and the use of photographs (stills and motion picture) in addition to particulate sampling. Both types of data were acquired by U.S. EPA personnel.

The shed leak opacity data are included in Appendix XX (Volume 7). These data were used to convert the peak mass emission rates of the leaks, which averaged 1-1/4 minutes in duration, to a continuous (about 13 minutes) fugitive emission rate. The photographs were used to estimate the average cross-sectional area of the fugitive plumes. Together with the fugitive particulate concentration data discussed in Section 5.1.2, these visual estimations were used to determine the continuous emission rate of fugitive emissions. The methodology is discussed in detail in Appendix HH (Volume 5).

5.6.3 Percent of Doors Leaking

An additional component of the coke-side particulate emissions, door emissions, appeared to be predominantly independent of either coke-pushing or quench car particulate emissions. Therefore, an observation technique which recorded the quantity of oven doors leaking during a short-term observation period was developed. Any visible leak from a door was considered a door leak. A number of coke-side oven doors were usually obscured by the coke guide during the short observation period, and therefore, the quantity of these obscured doors was also recorded. These observations yielded an estimate of the percent of coke-side doors leaking. Similar observations were obtained and results calculated for the push side of the coke battery and for both sides of Battery No. 2 for process documentation purposes. All field data sheets documenting door-leak observations are presented in Appendix VV (Volume 7).

Table 5.6.3 presents the door-leakage data for Batteries 1 and 2 on the days of particulate sampling. These results indicate that coke-side oven door leakage varied, ranging from 27 to 69 percent on Battery No. 1 and from 39 to 64 percent on Battery No. 2. Push-side oven door leakage was somewhat less variable than coke-side oven door leakage; it ranged from 26 to 37 percent on Battery No. 1 and from 8 to 19 percent on Battery No. 2. Finally, push-side chuck door leakage was the least variable type of door leakage, ranging from 18 to 22 percent on Battery No. 1 and from 36 to 47 percent on Battery No. 2.

TABLE 5.6.3

DOOR LEAKAGE ON PARTICULATE SAMPLING DAYS

Barnes Barber Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Coke Oven Battery	1975 Date	Coke-Side Oven Doors			Push-Side Oven Doors			Push-Side Check Doors		
		Number of Doors Observed	Number of Doors Leaking	Percent of Doors Leaking	Number of Doors Observed	Number of Doors Leaking	Percent of Doors Leaking	Number of Doors Observed	Number of Doors Leaking	Percent of Doors Leaking
No. 1 (Shedded)	3/4	58	40	67	57	21	37	57	19	38
	3/5	55	15	27	54	14	26	54	12	22
	3/6	63	31	49	63	23	37	63	13	21
	Average (Total)	(176)	(86)	49	(174)	(58)	33	(174)	(82)	28
No. 2 (Unshedded)	3/4	69	44	64	68	13	19	68	32	47
	3/5	62	27	44	61	9	15	61	21	36
	3/6	72	28	39	72	6	8	72	28	29
	Average (Total)	(203)	(99)	49	(201)	(28)	14	(201)	(82)	41

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5.7 Emission-Related Correlations

Since this project was essentially investigative in nature, several process parameters and indices of visible emissions were examined to determine whether they were directly related to the emissions measured. Many potential correlations were examined, using both the emission factor obtained from pushing operation samples and the emission factors obtained from continuous particulate samples. Supportive information for this section and additional attempted correlations are provided in Appendices SS to FFF (Volumes 7 to 12).

5.7.1 Correlations Between Emission Factors and Indices of Visible Emissions

Emission factors for continuous particulate samples were presented in Table 5.1.1. Indices of visible emissions for these samples — degree of greenness and opacity for the peak emission period — were presented in Tables 5.6.1-1, 5.6.1-3, and 5.6.1-5. Linear correlation techniques reveal no statistically significant relationship between the three continuous filterable particulate emission factors and average degree of greenness or average opacity. The linear correlation coefficients for the three pairs of data involved in these two potential relationships were 0.419 and -0.143, respectively.

Correlations were also attempted using the three filterable particulate push-only emission factors given in Table 5.1.3 and the indices of visible emissions for peak particulate samples shown in Tables 5.6.1-2, 5.6.1-4, and 5.6.1-6. Again, linear correlation techniques yielded no statistically significant relationships between these

parameters. The linear correlation coefficients for these potential relationships with degree of greenness and species were 0.070 and 0.281, respectively. In each of these cases, the small quantity of data available may have partially caused the poor correlations.

3.7.2 Correlations Between Emission Factors and Process Conditions

Net coking time and average flue temperatures for the continuous particulate sampling were summarized in Tables 3.6.1-1, 3.6.1-3, and 3.6.1-5. Correlation techniques using these parameters and the three continuous filterable particulate emission factors yielded no statistically significant relationships. The linear correlation coefficients for potential relationships with net coking time and average flue temperature were -0.761 and 0.189, respectively.

Correlations were also attempted using these same two process conditions for peak particulate samples and the three push-only filterable particulate emission factors. Although the linear correlation coefficient for the potential relationship with net coking time was quite high, -0.949, no statistically significant relationship was found. When the logarithms of these values were used, an even higher linear correlation coefficient resulted, -0.976. Nevertheless, this value, as well, was not statistically significant, likely because only three particulate samples were obtained. The correlation coefficient for the emission factor as a function of average flue temperature, 0.405, was also not significant.

5.7.3 Correlations Involving Particle Size Distributions

The particle size distributions were presented graphically in Figure 5.4, and characteristics of the distributions were given in Table 5.6.1-7. Using these data, linear correlations were attempted between the distributions and characteristics of the pushes. Although the correlation coefficients were quite high, no statistically significant correlation was apparent between variations in size distribution (weight fractions less than one micron and weight fractions less than five microns) determined for each of the samples and the greenness of the push. This was likely due to the few data pairs available (one of the four samples was lacking greenness data).

No statistically significant correlation was apparent, either, between particle size and net coking time. It was not possible to correlate particle size with flue temperatures or opacity because of the lack of data in both categories.

5.7.4 Correlations Between Indices of Visible Emissions and Process Conditions

Two parameters in this study can be considered as indices of visible emissions: opacity and greenness. The values for these two indices during particulate sampling were indicated in Tables 5.6.1-1 through 5.6.1-6. Two parameters which can be considered indicative of process conditions were also shown in these tables: net coking time and flue temperature. In order to determine whether these

indices of visible emissions could be considered a function of process conditions, several correlations were attempted. To use the most complete data base possible, the data in Tables 5.6.1-1 through 5.6.1-6 were combined with the other data obtained during particulate sampling days. All data sets can be found in the tables in Appendix 22, Volume 7.

Peak opacity was found to be highly correlated with net coking time during particulate sampling days. Several relationships were evaluated using these data, including the linear form, logarithms, and inverses. A relationship involving inverses, however, was found to be statistically superior. A modification to the net coking time variable, subtraction of a constant of 1000 minutes, improved the correlation further. The constant factor of 1000 was selected because none of the net coking times witnessed in a review of two years of data from the Burns Harbor Plant was less than this value (Appendix 22, Volume 7).

The final regression function, plotted in Figure 5.7.4-1, was found to be:

$$\frac{1}{\text{Peak Opacity}} = 0.0386 + 0.730 \left(\frac{1}{\text{NET} - 1000} \right).$$

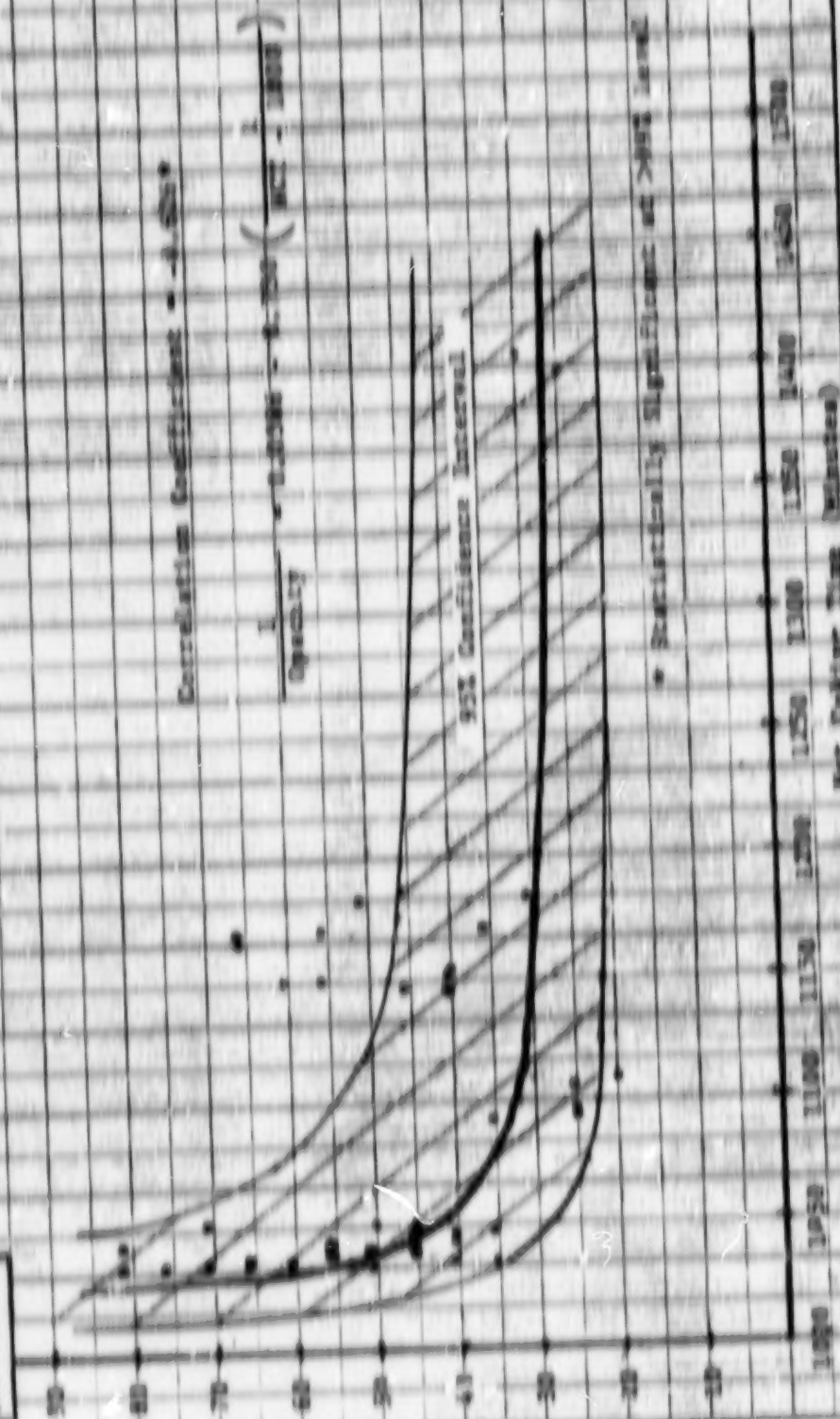
The correlation coefficient for this relationship, which comprised 60 pairs of data, was -0.626. This value is statistically significant at a level exceeding the 99-percent level.

A very highly statistically-significant correlation was also obtained for greenness as a function of net coking time for the particulate sampling days. Again several forms

FIGURE 5.7.4-1
NET COKING TIME VERSUS OPACITY FOR
PARTICULATE SAMPLING DATA

Bessemer Harbor Plant
Bethlehem Steel Corporation
Chester, Indiana
March 3-7, 1975

Opacity
(Percent)



of the relationship were attempted, but the one relating the inverse of greenness and the inverse of net coking time minus a constant of 1000 was found to be superior:

The regression equation, which is plotted in Figure 3.7.4-2, was:

$$\frac{1}{\text{Greenness}} = 0.00510 + 0.0431 \left(\frac{1}{\text{NET} - 1000} \right) :$$

The linear correlation coefficient for this relationship, which comprised 104 sets of data, was -0.333. This coefficient is statistically significant at a level exceeding the 99-percent level.

Correlations were also attempted using a second process: conditions parameter — average flue temperature. When peak opacity was considered as a function of flue temperature, a function involving the logarithm of temperature was found to be superior. The regression equation, which is plotted in Figure 3.7.4-3, was:

$$\text{Peak Opacity} = 4132 - 323 \left[\ln(\text{Temp}) \right] :$$

The correlation coefficient for this relationship, which involved 34 sets of data, was -0.633. This value is significant at a level exceeding the 99-percent level.

A potential relationship between greenness and flue temperature was also considered. The linear relationship between the logarithms of both values was found to be superior. The equation, which is plotted in Figure 3.7.4-4, was:

$$\ln(\text{Greenness}) = 75.8 - 9.04 \left[\ln(\text{Temp}) \right] :$$

Degree of Greenness
(Sum x Duration)

FIGURE 5.7.4-2

DEGREE OF GREENNESS VERSUS NET COOKING TIME
FOR PARTICULATE SAMPLING DAYS

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Correlation Coefficient = -0.95*

$$\frac{1}{\text{Greenness}} = 0.00580 - 0.0001 \left(\frac{\text{Net Cooking Time}}{1000} \right)$$

95% Confidence Interval

* Statistically significant at 95% level

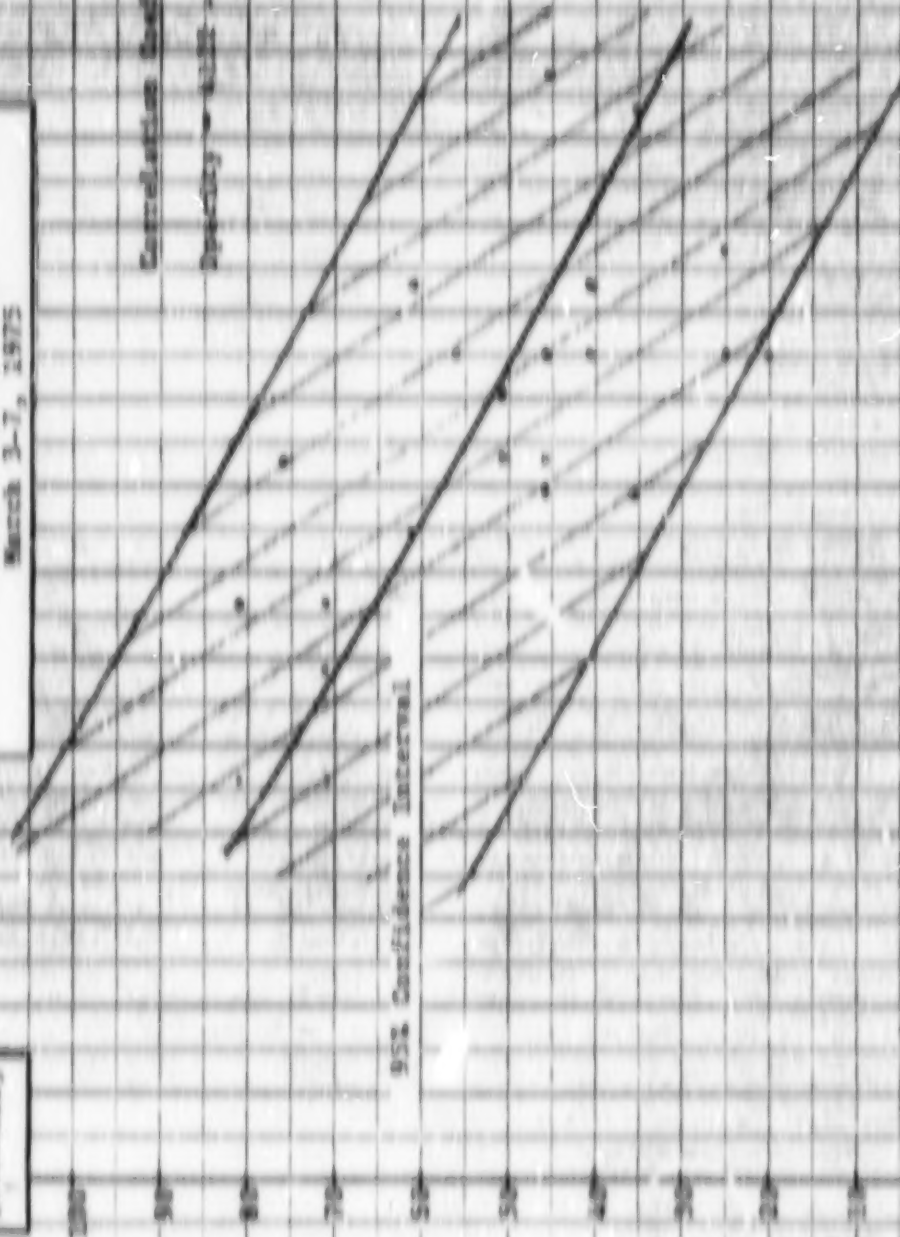
Net Cooking Time (Minutes)

FIGURE 5.7.4-3

OPACITY VERSUS FLUE TEMPERATURE FOR
PARTICULATE SAMPLING DATA

Borus Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Opacity
(Percent)



95% Confidence Interval

Correlation Coefficient = 0.955

Opacity = 0.0018 * Temperature - 403.5

* Statistical significance > 0.05 level

Average Flue Temperature (°F)

Degree of Greenness
(Sum + Duration)

FIGURE 5.7.4-4

MEANS OF GREENNESS VERSUS TIME TEMPERATURE
FOR PARTICULATE SAMPLING DATA

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

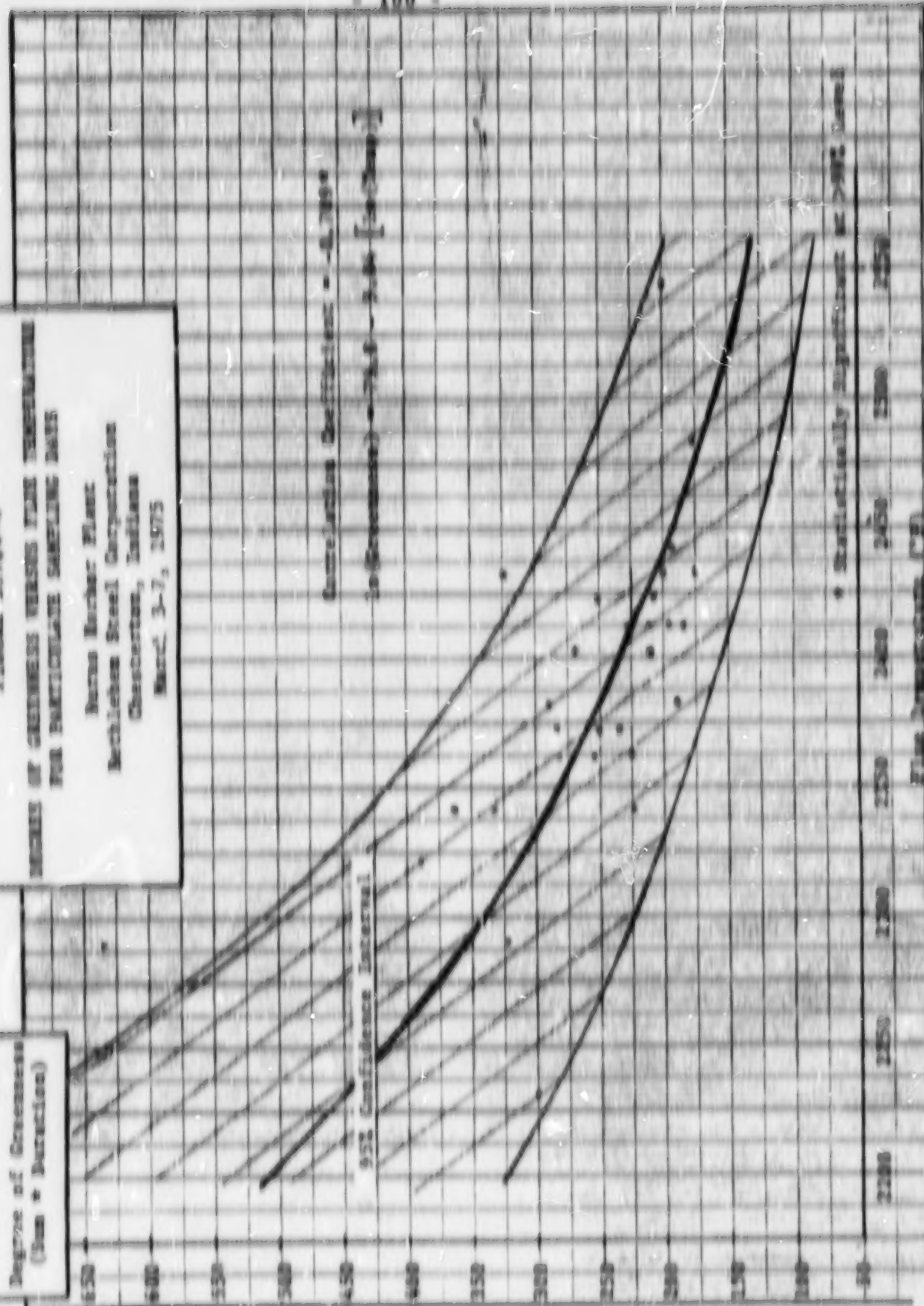
Correlation Coefficient = -0.789

Intercept = 74.8 - 3.46 (x 10⁻³)

95% Confidence Interval

* Statistically Significant at 95% Level

Time Temperature (°F)



The correlation coefficient for this relationship, which involved 31 pairs of data, was -0.709. This value is statistically significant at a level exceeding the 99-percent level.

5.7.5 Correlations Among Visible Emissions Measurements

Attempted correlations involving opacity as a function of greenness for the particulate sampling days also resulted in a highly statistically-significant correlation. The final equation, which is plotted in Figure 5.7.5-1, was:

$$\text{Peak Opacity} = -166 + 39.0 [\ln(\text{Greenness})]$$

The correlation coefficient for this relationship, covering 34 sets of data, was 0.646; the statistical significance of this value exceeds the 99-percent level.

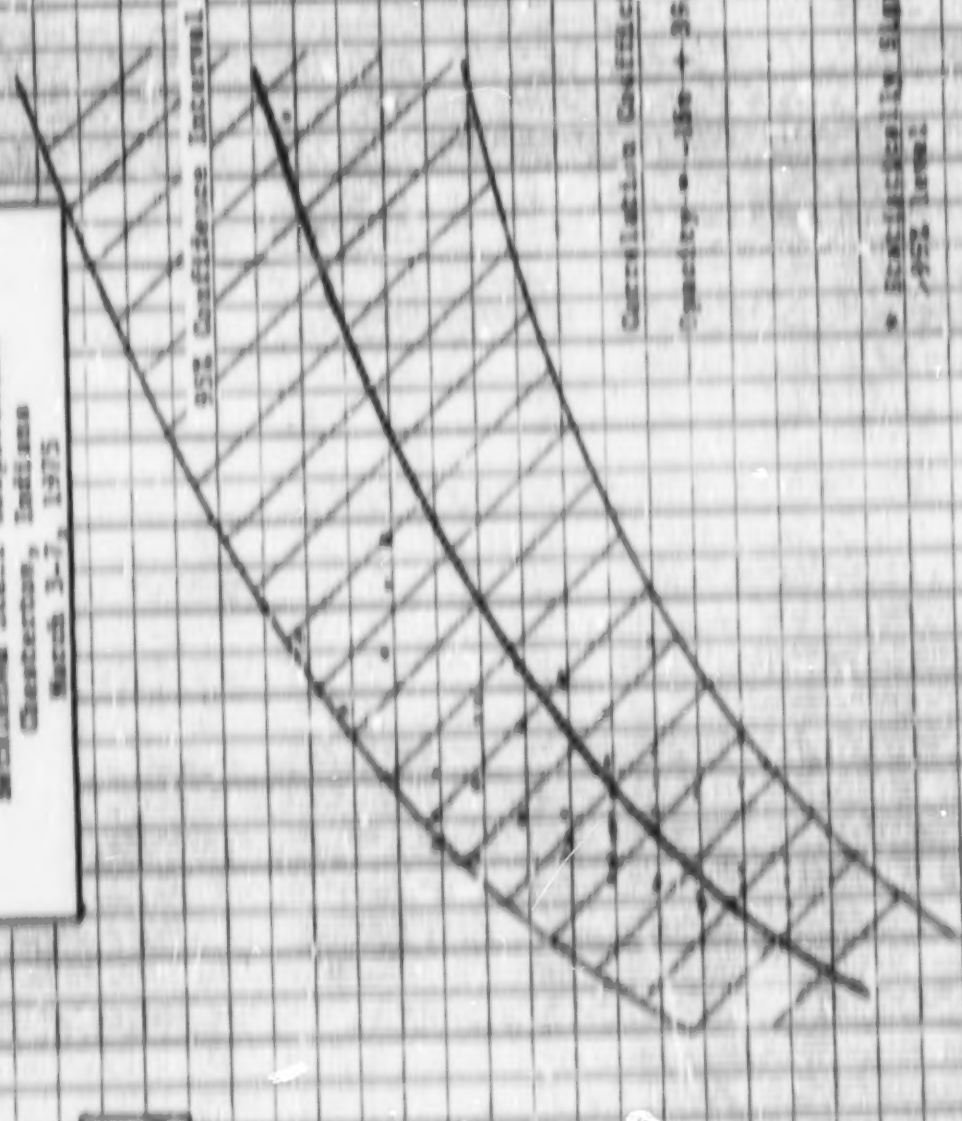
In order to further evaluate the opacity of the emissions from the shed exhaust stack, the opacity data obtained during particulate sampling days were combined with all available opacity data taken by certified visible emission observers during a one-year period prior to the start of the field testing. The results were then grouped in two ways. The first method clustered the data into the four categories listed below:

1. Particulate test days (typical, normal conditions only);
2. Non-test days (typical, normal conditions only);
3. Typical but abnormal conditions (i.e., coke-pushing cycle duration exceeding 30 minutes); and
4. Typical but abnormal conditions (i.e., net coking time greater than 18-1/2 hours).

FIGURE 5.7.5-1
 SPECIFIC VOLUME INDEX OF GREYNESS FOR
 PARTICULATE SAMPLING DAYS
 Burns Harbor Plant
 Bethlehem Steel Corporation
 Chester, Indiana
 March 3-7, 1975

Specific
 Volume
 Index
 (Percent)

90
80
70
60
50
40
30
20
10



20 100 150 200 250 300 350 400 450 500 550 600 650
 Degree of Greyness (mm. Diameter)

The opacity data, taken at intervals of approximately 15 seconds, were then averaged for each of these four categories. The results are plotted in Figure 5.7.5-2. The numbers in parentheses above each line on the graph indicate the number of sets of data averaged to obtain the curve.

To investigate this relationship further, the data were regrouped based upon net coking time. Six 15-minute net coking time intervals were established, using the 1,035-minute minimum net coking time specified by Bethlehem Steel Corporation as a baseline. The results are plotted in Figure 5.7.5-3. Again, the numbers in parentheses above each line on the graph indicate the number of data sets averaged to obtain the curve. This figure indicates that increasing net coking time yields predictably decreasing shed exhaust opacities.

5.8 Effect of the Shed Upon Dustfall

In addition to collecting door, quench car movement, and pushing emissions, the shed on Battery No. 1 also acts as a large settling chamber for coarse dust, especially along the shed wall. During a push, and for a period of about two or three minutes thereafter, a worker or observer under the shed may experience a "fallout" of settleable particulate matter along the length of the shed, especially along the shed wall.

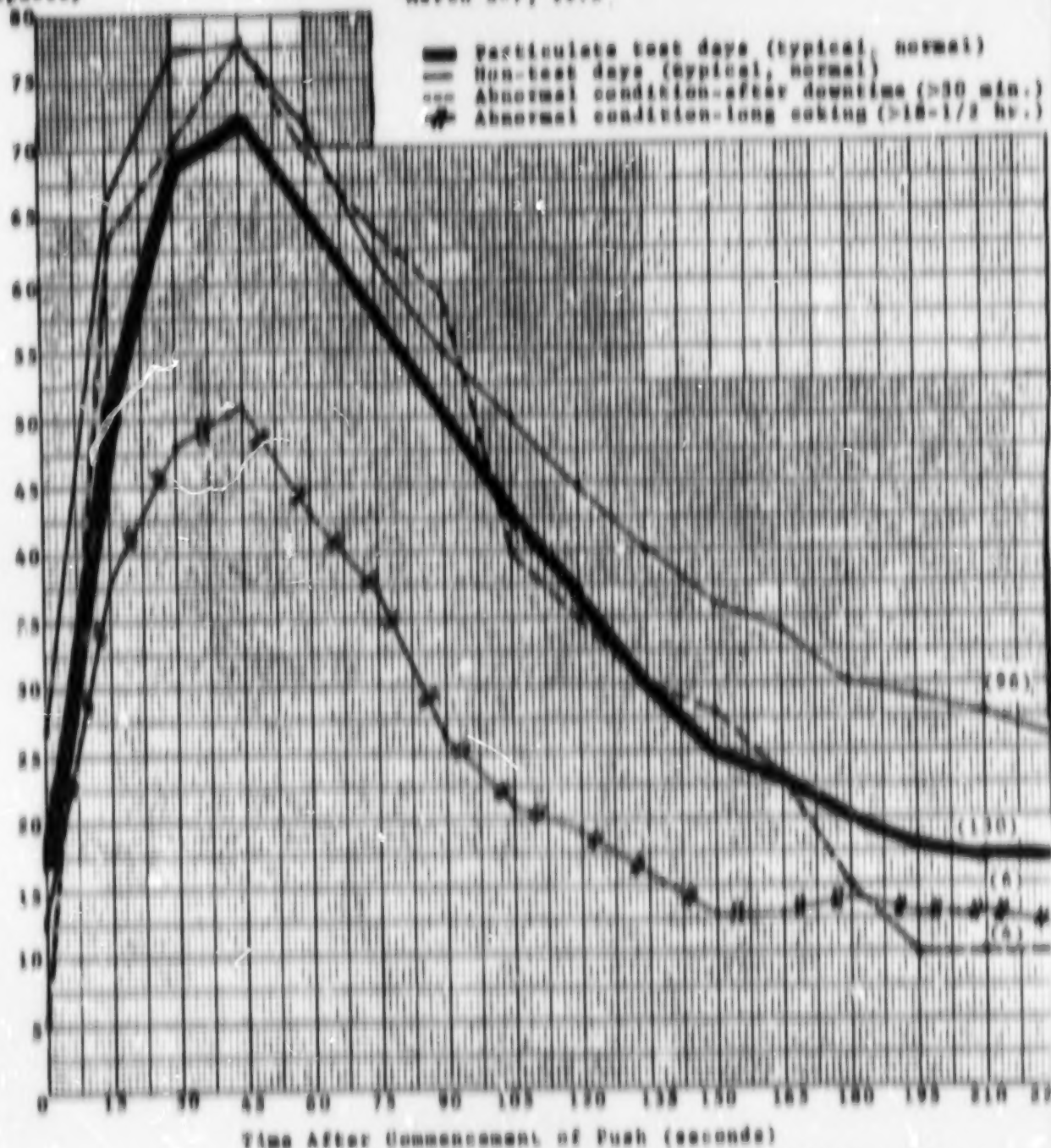
To determine the magnitude of this effect, and to determine how it varies with location, dustfall (settleable particulate) measurements were made on and about both Batteries 1 and 2. Dustfall jars were exposed at fixed locations on both batteries:

FIGURE 3.7.3-2

COMPOSITE GRAPH OF SMOG EXHAUST DUCT OPACITY VERSUS TIME

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

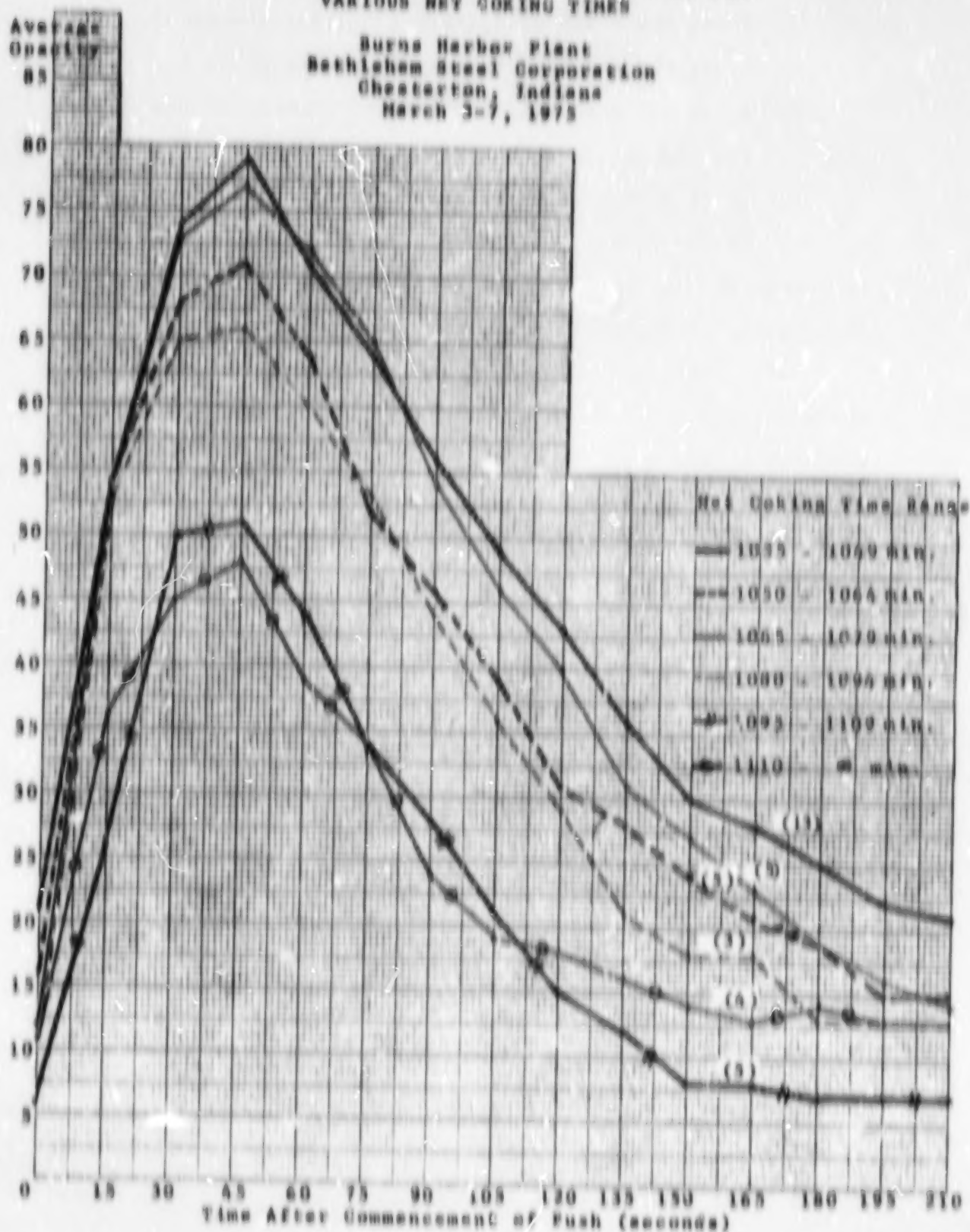
Average
Opacity



Clayton Environmental Consultants, Inc.

BHED EXHAUST DUST OPACITY VERSUS TIME FOR
VARIOUS NET COKING TIMES

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975



1. Along the bench of Battery 1 (under the shed);
2. Along the bench of Battery 2 (unshedded);
3. Along the shed wall of Battery 1, about 10 feet from the side of the bench; and
4. Along a line geometrically equivalent to that described in (3) above, near Battery 2.

It should be kept in mind that this technique provides only relative values of dustfall intensity.

Table 3.8-1 shows dustfall data for comparable locations on Batteries 1 and 2. The units in each case are grams/m²/week (convertible to the usual "ambient" units of tons/mi²/month by multiplying by 11.4). The geometric mean value for each location is also reported. All dustfall sampling periods, dustfall weights, and the percentage of particulate matter collected on the sieve are presented in Appendix GGG (Volume 12).

In comparing the data in Table 3.8-1, several general comments should be kept in mind:

1. Pushing emission rates for these two coke batteries are not necessarily identical. The batteries are of different design with respect to their heating system, Battery 2 being newer.
2. Battery 1 produces about 10 percent more coke per hour.
3. Variations in wind speed and direction may affect the significance of the data.

A shed visitor's perception that dustfall is severe under a shed should be interpreted in the context of the physical position of the observer. It is common for such observations to be made at ground level near or under the shed wall on the far side of the

TABLE 5.8-1

SUMMARY OF DUSTFALL MEASUREMENTS AT BATTERIES 1 AND 2
($\mu\text{m}/\text{m}^2/\text{wk}$)

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Sampling Location	1975 Sampling Period						Geometric Mean
	3/2-4	3/4	3/4-5	3/5	3/5-6	3/6	
Shedded Spare Door A	—	1560	3700	3260	3080	332	1830
Unshedded Spare Door +	198	56	275	2320	352	222	286
Bench 123	—	7690	3300	484*	4812	2840	3320
Bench 152 A	—	2410	3650	—	—	6270	3810
Bench 178	—	3790	3030	—	3390	5000	3800
Shedded Bench Geometric Mean	—	2910	3320	—	4160	4670	3620
Bench 223	1400	6010	3800	1710	2000	2300	2510
Bench 252 +	2930	1500	3380	6010	2540	—	2730
Bench 275	2010	26,900*	4840	2320	2080	4300	2890
Unshedded Bench Geometric Mean	2020	3000	3910	2320	2190	3120	2690
Ground 151 A	26,600	21,900	—	27,800	22,800	28,200	26,600
Ground 177	12,000	15,300	11,200	7340	11,100	30,600	13,100
Shedded Ground Geometric Mean	17,900	18,300	11,200	16,300	15,700	27,700	17,500
Ground 236	357	1130	—	—	5*	120	365
Ground 251 +	650	—	643	1010	136	739	696
Ground 277	131	692	376	—	—	137	250
Unshedded Ground Geometric Mean	253	746	610	1010	136	230	365
Shedded Wall Wall 121 A	11,600	11,600	12,300	18,600	16,300	10,600	13,200
Mid 1	3180	6110	—	3550	—	2380	3260
Mid 2 ** A	1980	5830	—	3370	—	2410	2850
Shedded Mid Geometric Mean	2090	4900	—	3460	—	2390	3040
End 1 ** A	1530	1530	—	1630	—	3640	1930
End 2	1280	2360	—	1780	—	1670	1770
Shedded End Geometric Mean	1400	1980	—	1700	—	2670	1850

* Statistical tests indicate that these values are suspect. They were not used in the statistical analyses.

** Duplicate Samples

A Battery No. 1

+ Battery No. 2

Clayton Environmental Consultants, Inc.

quench car tracks. For reasons of accessibility and safety, it is easier to observe there than on the coke-side bench, which offers no clearance between a battery and its door machine. Dustfall under the wall is not necessarily representative of a work station, i.e., normal worker exposure.

In addition, the small numerical difference in Table 3.8-1 between dustfall rates at bench locations on the shedded and unshedded batteries means that the shed had no apparent measurable effect on dustfall at this key work station.

Table 3.8-2 presents the acetone-soluble and cyclohexane-soluble content of five selected dustfall samples. Neither extraction resulted in a concentration which exceeded 0.1 percent. Table 3.8-3 presents the pH of five other samples; the values ranged from 6.0 to 7.1.

In order to identify how the coke-side shed affects measurable dustfall rates, other potential influential factors were first evaluated. These other variables were: a) greenness of the pushes, b) pushing rate, and c) location of the dustfall bucket. The data shown in Table 3.8-1 were used for the analyses. All statistical analyses were performed using the logarithms of the dustfall rates since dustfall rates are known to be log-normally distributed. (4)

Because dustfall measurements inherently are relatively crude, the precision (reproducibility) of the method was estimated by exposing pairs of dustfall jars at the same site. The eight pairs of samples identified in Table 3.8-1 as "mid" and "end"

TABLE 5.8-2
SUMMARY OF ACETONE SOLUBLE AND
CYCLOHEXANE SOLUBLE CONTENT
OF SELECTED DUSTFALL SAMPLES

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Site	Sampling Period				Percent Acetone Solubles	Percent Cyclohexane Solubles
	Start		Stop			
	Date	Time	Date	Time		
Ground 177	3/3	16:47	3/4	09:17	0.008	0.002
Well 121	3/3	16:31	3/4	09:09	0.002	0.004
Bench 278	3/4	08:26	3/4	15:49	0.005	0.006
Bench 223	3/4	15:44	3/5	10:19	0.087	0.01
Bench 152	3/6	09:52	3/6	17:46	0.042	0.02

TABLE 3.8-3
SUMMARY OF pH OF
SELECTED DUSTFALL SAMPLES

Burns Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Site	Sampling Period				pH of Sample
	Start		Stop		
	Date	Time	Date	Time	
Bench 152	3/4	08:17	3/4	15:30	6.6
Ground 151	3/3	16:40	3/4	09:10	6.2
Hid 1	3/6	09:42	3/6	16:01	7.1
End 1	3/3	17:12	3/4	09:10	6.0
End 2	3/4	10:35	3/4	16:30	7.1

samples were simultaneous pairs. To determine the precision of each of these pairs of samples, the difference in the logarithms of the paired values was divided by the geometric mean of the pair. These precision values ranged from 0.3 to 11 percent. These eight precision values were then evaluated to determine if any pair could be considered an "outlier." No pair of samples could be classified as an outlier by this method. In all additional evaluations, the geometric mean dustfall rate was then used for the paired samples. The "mid" and "end" samples are indicated in further analyses as "ground" samples taken at the 4-foot level.

An average greenness for ovens pushed during each dustfall sample was determined by averaging the "sum times duration" values for the pushes that occurred during the sampling period. These average greenness values were then arranged in ascending order and a median value of 230 found. All greenness values below 230 were labeled "low" and all above 230 were labeled "high." It is important to note that 77 percent of the pushes under the shed had high average greenness values while only 14 percent of the unshedded pushes had average greenness values that were considered high.

Pushing rate for a dustfall sample was determined by counting the number of either shedded or unshedded ovens, as applicable, that were pushed during a sample and dividing by the time duration of the dustfall sample. Again the values were arranged in ascending order and the median was found to be 4.7 pushes per hour. All pushing rates below this value were considered "low" and all rates equal to or above this value were considered "high."

The dustfall data were then arranged into several cells in order to best eliminate any confounding effect of the multiple variables. These cells, shown in Table 5.8-4, were determined by first dividing the data into that applicable to shedded and unshedded areas. Each area was subdivided into one of four common locations: "spare door," "bench," "ground" at the 4-foot level, or "ground" at the 10-foot level. Other locations sampled in this study were not used in the analyses because samples taken at these locations were taken only within the shed. The next two subdivisions were those of "low" and "high" pushing rates and "low" and "high" greennesses. Tests for outliers were then conducted within each of these cells; a single cell now contained the most homogeneous subset of data available. Only the three values indicated in Tables 5.8-1 and 5.8-4 were found to be outliers.

In order to determine whether greenness and dustfall rate were correlated, the number of subdivisions was reduced by one so that greenness was no longer used as a basis of subdivision. In each of the remaining 16 cells, the logarithm of dustfall rate for each sample was paired with its average greenness value. The linear correlation coefficient for the pairs in each cell was then determined. Only the value for the nine shedded bench samples with low pushing rates was found to be significant at the 95-percent level. On the basis of the fact that only one of the correlation coefficients was found to be significant, it was concluded that the relationship between greenness and dustfall rate was not significant for the overall data set.

TABLE 5.8-4

FORMAT USED FOR ANALYSES OF DUSTFALL DATA (gm/m²/wh)

Purne Harbor Plant
Bethlehem Steel Corporation
Chesterton, Indiana
March 3-7, 1975

Greenness	S h e d d e d				U n s h e d d e d			
	Low		High		Low		High	
Pushing Rate	Low	High	Low	High	Low	High	Low	High
Spare Door	1,660		3,700 3,360 3,080	332	275	56 352 222		2,320
Bench	2,690 2,610 3,790		3,300 486* 4,810 3,650 6,270 3,050 3,590	2,840 5,000	3,800	6,010 2,000 2,306 1,500 3,380 2,520 26,900* 4,640 2,320 2,080 4,500		1,710 4,010
Ground (4' level)	4,900 1,980		3,460 1,700	2,390 2,470	136 137	1,130 9* 120 643 739 692 576		1,010
Ground (10' level)	21,900 15,300 11,400		27,800 22,200 11,200 7,340 11,100 13,500 18,400 16,300	25,200 30,400 10,600				

* Statistical tests indicate that these values are suspect. They were not used in statistical analyses completed after the test for outliers.

Since greenness and dustfall rate were not found to be correlated, those dustfall rates which did not have a greenness rating associated with them could now be included in further analyses. Thus, these values were added to their respective cells determined in the previous analysis, and the tests for outliers were repeated. No additional suspect values were found.

The correlation between pushing rate and dustfall rate was evaluated next in a similar manner. The number of subdivisions was reduced by one by eliminating pushing rate as a basis of subdivision. In each of the remaining eight cells, the logarithm of dustfall rate was paired with its pushing rate. The linear correlation coefficient was determined for each cell. None of the values was found to be significant at the 95-percent level. It was thus concluded that pushing rate and dustfall rate were not correlated for this set of data.

Two factors remained to be considered -- the location of the dustfall bucket and the shed effect, i.e., shedded versus unshedded areas. To determine whether or not location was a significant factor, two separate one-way analyses of variance were performed. The door-bench-ground location samples were compared to each other for the shedded and unshedded areas. Under the shed, the geometric mean of the 10-foot-level ground samples was significantly higher than that of the other three locations. The geometric mean of the bench samples, in turn, was significantly higher than the geometric mean of the spare door samples. The geometric mean of the 4-foot-level ground samples did not differ significantly from that of the bench samples or the spare door samples.

For the unshedded area, the geometric mean of the bench samples was found to be significantly higher than the geometric means of the 4-foot-level ground samples and the spare door samples. In this area, the geometric mean dustfall rates for the ground samples and the spare door samples were essentially the same.

Since location of the dustfall bucket appeared to be a significant factor, a one-way analysis of variance was done for each of the locations to determine whether or not the shed was a significant factor. At three of the four locations — the spare doors and both ground levels — the geometric mean dustfall rates under the shed were found to be significantly higher than those for samples not taken under the shed. However, for the bench location the geometric mean dustfall rates under the shed were not statistically different from those found at the unshedded location. It can thus be concluded that both the presence of the shed and the location of the dustfall bucket have a significant influence upon measured dustfall rates in this study.

5.9 Impact of the Shed Upon Airborne Agents Within the Shed

The question of whether a semienclosed shed adjacent to a coke-oven battery has a significant effect upon the quality of the work environment within the shed was not addressed in this study. Two studies by the National Institute of Occupational Safety and Health (NIOSH), however, did address this issue. (5,6)

5.10 Precision of Test Results

Although the terms "precision" and "accuracy" are often regarded as synonymous, they do have different technical meanings. The accuracy of a measurement signifies the closeness with which

the measurement approaches the true value. Precision, on the other hand, characterizes the repeatability of the measurements. Thus, the precision of a measurement denotes the closeness with which a given measurement approaches the average of a series of measurements taken under similar conditions. Clearly, if the bias is large, a measurement may be very precise but very inaccurate.

Many techniques exist to evaluate the precision of a result. Ideally, simultaneous replicate samples are taken and the coefficient of variation, the standard deviation expressed as a percentage of the mean, is used as a measure of precision. This technique was used for eight pairs of dustfall samples taken in this study and reported in Section 3.8.

When the sample at hand is the only measure of the variability of data at given conditions, a confidence interval may be used to bracket the true mean of the population. This interval may be regarded as a first estimate of the precision of the results. In this study, such confidence intervals were constructed at the 95-percent level, implying a 5-percent risk of not bracketing the true mean of a series of test measurements. This confidence interval is expressed in the Summary and Conclusions (Section 2.0) as $m (\pm r)$, where m is the arithmetic mean and $2r$ is the confidence interval. This technique was used in the evaluation of particulate emission rates and emission factors.

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John E. Hutchier, P.E.
Richard J. Fowles, P.E.
Janet L. Verschie

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6. National Institute for Occupational Safety and Health, Division of Technical Services, Industrial Hygiene Services Branch, "An Industrial Hygiene Survey of the Great Lakes Carbon Corporation (Missouri Coke & Chemical Division) Coke Side Emission Collecting Shed," Project No. 75-31, April 28, 1975.

7.0 SOME ANTICIPATED QUESTIONS AND ANSWERS
RELATIVE TO THIS PROJECT

1. Q: Were these emission tests truly representative of the typical conditions occurring at Coke Battery No. 1 at the Burns Harbor plant?

A: Yes. A great deal of care was taken and much documentation was obtained to ensure that both the process operations and the sampling and analytical procedures would accurately represent typical conditions existing at the subject battery (see Section 3.2).

2. Q: Just how reasonable is the choice " $\pm 10\%$ " for defining typical conditions?

A: Quite reasonable. Basically, two off-setting conditions are at work. One is the inherent variability of process parameters and the other is the need for maintaining, as close as possible, maximum operating conditions during the test period which are representative of "normal" conditions. We believe that $\pm 5\%$ is probably too strict a criterion for process variables which would not materially affect the outcome of testing. However, anything more than $\pm 10\%$ could very likely cause significant changes in emission concentrations, rates, and characteristics. Therefore, the criterion of $\pm 10\%$ was chosen to represent "typical" conditions.

2. Q: Were the frequency and extent of our observations sufficient to characterize the particulate emissions as a function of process input rate?

3. A. While emission factors and emission rates did not correlate significantly with process input rate, some related correlations were found to be significant statistically. These correlations relating the indices of visible emissions to various process parameters, such as net coking time, proved significant. The fact that emission factors or emission rates could not be correlated to pertinent process parameters is due predominantly to the small number of data points available (three) for emission measurement tests. Because so much of the data acquired during these source tests appears to be relatively precise, several correlations were examined nonetheless.

4. Q. Why was the term "tons of dry coal fed" used as a normalization factor?

A. Dry coal feed rate rather than wet coal feed rate was used because it was an accurate measurement and compatible with a mass balance concept which historically has been the "process weight rate" method of normalizing emission data to production rate.

5. Q. Does the Burns Harbor study provide sufficient basis for expressing an emission factor for coke-side emissions?

A. The Burns Harbor tests provide emission factors for coke-side emissions for a host of contaminants for a single coke-oven battery at a single production rate and a relatively narrow range of operating conditions. Nonetheless, the degree to which data analysis has revealed statistically significant correlations between emission factors and

process parameters indicates that extrapolation of these results to other batteries may be appropriate and meaningful only if similar ranges of process parameters exist at the untested battery. Such emission factors should, however, be refined as more data are acquired.

6. Q. Why were so many correlations attempted?

A. This study was, in some ways, a prototype for subsequent studies. Therefore, it was important to learn the relationships, if any, between process and emission variables that could describe variations in emission rates.

7. Q. Were any especially good correlations developed as a result of this study?

A. Yes. Net coking time appears to be one of the most significant variables affecting at least the opacity and degree of greenness (see Figure 5.7.4-1 and 5.7.4-2) and probably the mass rate of particulate emissions, although data analysis did not reveal any significant correlations between emission factor and net coking time. This may also be true for other contaminants. However, no data were acquired to substantiate the latter postulation. Obviously, other process conditions must be maintained relatively constant for any of these correlations to be developed and, in fact, they were relatively constant during the Burns Harbor sampling. Unfortunately, the small number of particulate samples precluded the possible development of a statistical relationship between particulate emissions and other parameters.

8. Q. Who obtained the process information for this study?

A. Bethlehem Steel Corporation personnel gathered the information which was then provided either directly to U.S. EPA personnel or to Clayton personnel.

9. Q. Who obtained the sampling and analytical data?

A. Clayton personnel (see Appendix RR, Volume 6).

10. Q. Who obtained the visible emissions data?

A. U.S. EPA personnel (see Appendix RR, Volume 6).

11. Q. Were there any experimental (atypical) oven doors, unusual maintenance, or other peculiar operating conditions during the tests?

A. Yes. Experimental doors were observed in use on a few of the coke ovens. No unusual or abnormal maintenance or operating conditions were noted on any of the data provided to Clayton personnel.

12. Q. Did an analysis of Bethlehem Steel Corporation pollution and/or inspection reports document that the plant, or at least the oven doors, were being handled and/or maintained in an unusual fashion immediately before or during the test period as compared to other periods?

A. No. However, inspection reports are too infrequent to define these conditions very effectively (see Appendix YY, Volume 7).

13. Q. What is the optimum net coking time for reduction of emissions?

A. Without an analysis of the minimum net coking time necessary for preventing coke-oven "stickers," this answer cannot be provided.

14. Q. What is the best method of describing "greenness" in a quantified sense?

A. The product of the sum of the greenness ratings and the duration of the push was judged to be the best.

15. Q. Is there any specific reason for very green pushes?

A. This could not be determined with any degree of certainty simply because there weren't enough "very green pushes" to acquire statistical information. Only a few very green pushes were observed during the source testing. However, as mentioned previously, the shorter the hot coking time, apparently the greater the degree of greenness and the higher the opacity of exhaust duct emissions. An especially "cold" oven, operating significantly below the average cross-wall temperature of the other ovens, could very likely cause a very green push.

16. Q. Could the causes of leaks from the coke-oven shed be quantified sufficiently to indicate which variable was most significant regarding fugitive particulate emissions?

A. No. Too many independent variables were working together to affect leakage from the shed. These included wind, exhaust gas flowrate through the shed system, location of the oven pushed, greenness of a specific push, etc.

17. Q. Why was a three-minute peak sampling period chosen instead of a 2-1/2-minute peak period?

A. The three types of data acquired to obtain an accurate estimate of the maximum period of pushing emissions evacuation from the shed (temperature, filter obscuration, and opacity)

all indicated that the best measure of peak pushing emissions was one taken over a three-minute interval. In fact, the preliminary procedures to indicate and quantify this peak pushing emissions evacuation period were performed not only prior to beginning emission testing, but even during the preliminary tests on February 24, 1975 so that the best indicators possible of that subject period would be obtained. It turned out that the choice of three minutes was very propitious, especially when the data were evaluated after the source testing was performed. The opacity data indicated strongly that the choice of three minutes was not only fortunate but very accurate as well (see Figures 5.7.5-2 and 5.7.5-3).

18. Q: Why was the probe rotated in the stack rather than being pulled out between sampling points (for the peak emission tests)?

A: The insertion and withdrawal of the probe would more likely cause sampling error and possible sample losses. Additionally it was important to rotate the face of the nozzle away from the entering stream lines of the exhaust gas flow during non-sampling periods. Therefore, the face of the nozzle was rotated with the probe at least 90° off of facing directly into the exhaust gas flow whenever the sampling train was shut down.

19. Q: Why wasn't the attenuation coefficient a good indicator of the particulate concentration in the duct?

A. The closeness of the measured particulate concentrations among the three sample runs precluded the ability to distinguish between average attenuation coefficients for the continuous particulate emission tests. Thus, the attenuation coefficient may have been a good indicator of particulate concentration but could not be correlated with such a narrow range of average particulate emission concentrations.

20. Q. Was the proper path length utilized for attenuation coefficient calculations?

A. Yes. Mr. Kirk Foster of the U.S. EPA helped in this endeavor.

21. Q. Why were the probe and filter maintained at the temperature of the stack?

A. Because it was part of the objective to neither create nor diminish filterable particulate matter.

22. Q. How frequently was the A_p checked for isokinetic sampling?

A. It was monitored continuously. For peak sampling, it was recorded every 30 seconds (see Appendix LL, Volume 5).

23. Q. Why was acetone used rather than some other organic solvent for cleaning up the sampling train?

A. Not only is it the recommended procedure in U.S. EPA Method 5, but acetone effectively removes the deposition of particulate matter and allows for good clean-up of the components of the sampling train when sampling coke-oven emissions.

24. Q. Should cyclohexane be used as the solvent for sampling train clean-up for coke-oven particulate tests in the future?
- A. The results of sampling for cyclohexane solubles and insolubles presented in Section 5.5 indicate that cyclohexane may be a preferable solvent. Acetone was used in this study, however, because it is required by the standard EPA Method 5 procedure. In actuality acetone may be a better solvent because it is a better wetting agent than cyclohexane, i.e., removes particulate matter by wetting rather than solubility.
25. Q. How did we attempt to quantify the organic fraction of the particulate material?
- A. Through the use of acetone solubility, the cyclohexane capture technique, the activated carbon adsorption technique, and grab flask samples (see Appendix LL, Volume 5).
26. Q. How did we account for or avoid potential sampling and analytical problems with sulfate, nitrite, nitrate, hydrogen chlorides, and pseudo-particulate?
- A. By maintaining the sampling conditions very close to the stack conditions extant during the type of tests (whether continuous or peak), and with pre-planning regarding the analytical techniques used. These techniques minimized potential problems with pseudo-particulate generation in the impingers. The extent to which the aforementioned species affected results is minimal since particulate analyses reveal small amounts of these materials (see Tables 5.3-2 and 5.3).

17. Q: Do we have a true representation of the test period compared to the typical process at Battery 1 of the Burns Harbor plant?

A: Yes (see Section 3.3).

18. Q: How well do our particle size results represent the EPA Method 5 filterable particulate catch?

A: Very well (see Section 3.4 for complete details).

19. Q: Why were the peak and continuous particulate emission rates different for each test?

A: Because of variability of individual coke-even pushes and door leaks (see Tables 3.6.1-1 through 3.6.1-6).

20. Q: Why was the average "pushes per hour" figure for the continuous particulate samples slightly different than the typical condition?

A: Because sampling had to be interrupted at numerous times for process malfunctions and/or for changing the probe from port to port. Additionally, the procedure (stopping the sampling whenever the push-to-push time exceeded 30 minutes) slightly increased the pushes per hour figure. Nevertheless, it was still within the $\pm 10\%$ criteria (see Table 3.2.2-1). Further, even though this was the case, no apparent change in the emissions data occurred between the first continuous particulate sample run which operated at a rate of about 5.2 pushes per hour and the second and third tests which each operated at a rate of about 4.8 pushes per hour. Apparently, then, the push-per-hour

figure, which obviously related to the tons of coke charged per hour for each sampling period, is not a significant criterion for establishing an average continuous particulate emission rate from the coke battery.

31. Q: What was the stability of percentage of door leakage, whether push-side oven door, coke-side oven door, or push-side chuck door?
- A: Widely variable (see Table 3.6.3).
32. Q: Can we estimate from door leakage inspections how long it takes for a door to stop leaking?
- A: There are insufficient data to make this estimate from the data acquired at Burns Harbor (see Appendix VV, Volume 7).
33. Q: What was the stability of net coking time for the individual coke-oven pushes?
- A: Widely variable (see Appendix 22, Volume 7).
34. Q: What was the stability of greenness by oven day-to-day?
- A: Quite unstable except in the case of a few sets of ovens which apparently were responsible for slightly greener pushes (see Appendix 22, Volume 7).
35. Q: What was the stability of the percentage of moisture of the coal mix?
- A: Quite stable (see Appendix D, Volume 2).
36. Q: Who built Battery No. 1?
- A: Wilputte.

37. Q. Who built Battery No. 37

A. Koppers.

38. Q. How extensive were chain-of-custody procedures?

A. Very extensive. Someone from the Clayton crew was always present with the samples or the samples were locked securely in storage (see Appendix NN, Volume 6).

39. Q. Do you have other major recommendations for subsequent coke-oven test work?

A. Yes. Include a complete industrial hygiene/occupational health survey at the same time the emission testing is performed on a subject battery; acquire visible emissions data continuously during each particulate sample run; and continuously refine the required roster of materials to be measured.

40. Q. What reservations do you have regarding this study?

- A. 1. We believe the information acquired here, although of excellent quality, should not be extrapolated indiscriminately to all coke ovens.
2. It would have been helpful to substantiate (with "official" process information) that the pre-study average coal feed rate and the pre-study coke production rate were equivalent to those recorded during and after the study (see Table 3.2.2-1).